Laboratory 4: Introduction To Basic Electronic Test Equipment

- **Lab Overview (Beckwith Chapter 9 pp. 346 - 354)**

This Lab will span two weeks, with Part 1 performed during week 5 and part 2 during week 6. The Lab will investigate

- Alternating Current (AC) Signal Measurements
- Oscilloscope Triggering
- External Scope Triggering
- Effect of Sampling Rate and Signal Aliasing

Equipment Used will be

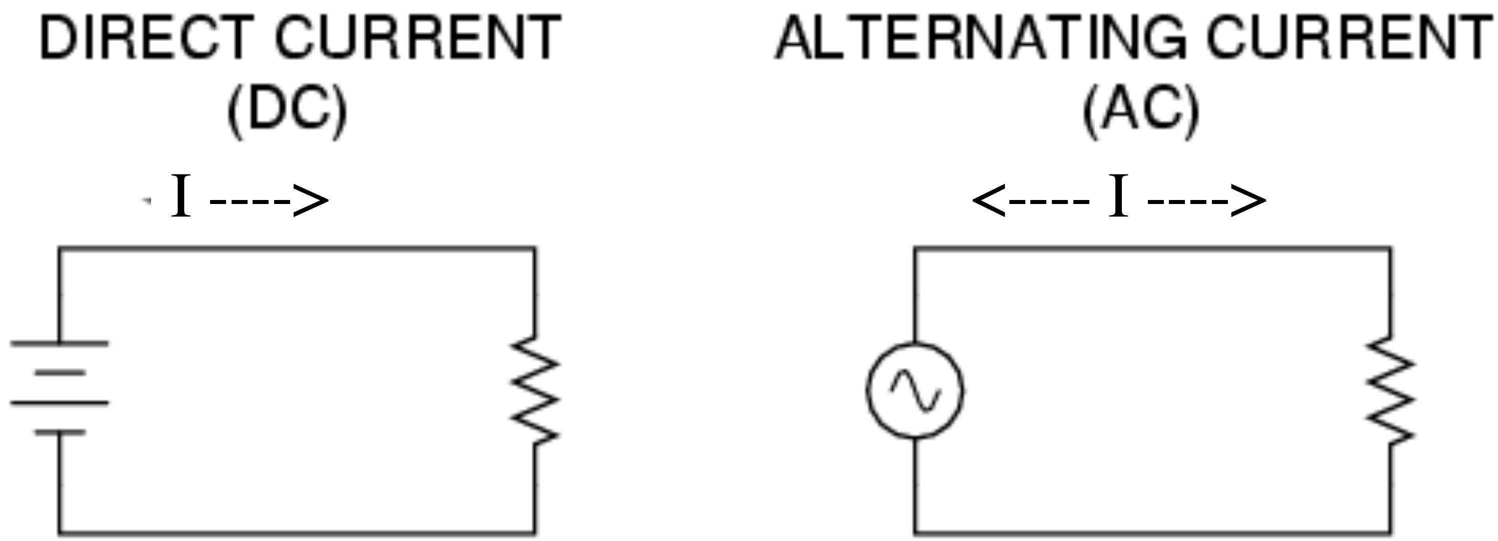
a) digital voltmeters (DVM's) benchtop and handheld-- sometimes called "multimeters"
b) signal generators
c) oscilloscopes
d) National Instruments Analog-to-Digital
(A-D) and Digital-to-Aanalog (D-A) Converters

Laboratory 4: Introduction To Basic Electronic Test Equipment (2)

One of the most important functions of the undergraduate Measurements Engineering lab is to provide a working understanding of the functions and uses of instruments commonly found in all electrical laboratories.

To the Engineering student, this knowledge is essential to efficiently conduct laboratory assignments and in developing independent design projects.

… so PAY ATTENTION!



• DC is the kind of electricity generated by a battery (with definite positive and negative terminals) .. ***Constant amplitude***

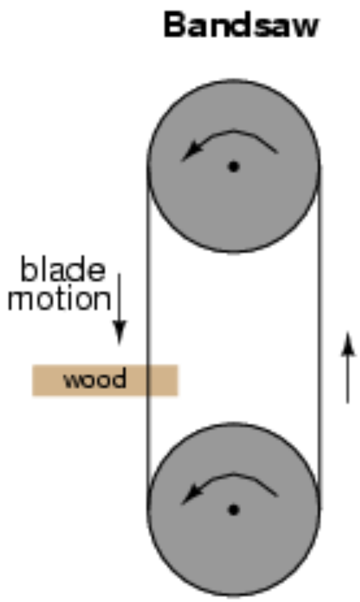
• AC is the kind of electricity Generated by a car's alternator ***Amplitude and Phase Components***

• Battery symbol is used as a generic symbol for any DC voltage source, the circle with the wavy line inside is the generic symbol for any AC voltage source.

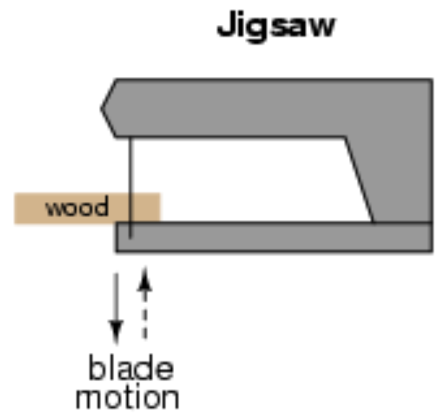
Alternating Versus Direct Current (1) http://www.ibiblio.org/obp/electricCircuits/AC/AC_1.html#xtocid296211

Alternating Versus Direct Current (2)

- Mechanical Analog



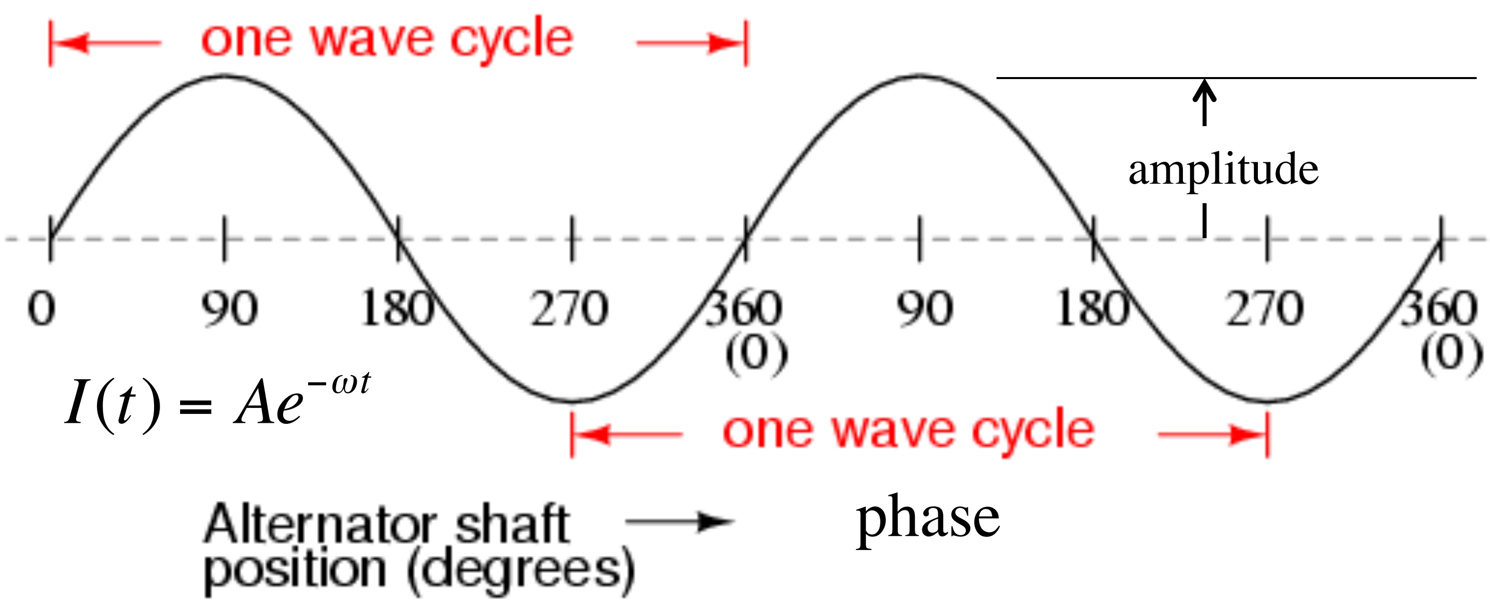
(analogous to DC)



(analogous to AC)

Alternating Current Waveform

• When an alternator produces AC voltage, the voltage switches polarity over time, but does so in a very particular manner. When graphed over time, the wave traced by this voltage of alternating polarity from an alternator takes on a distinct shape … *sine wave*



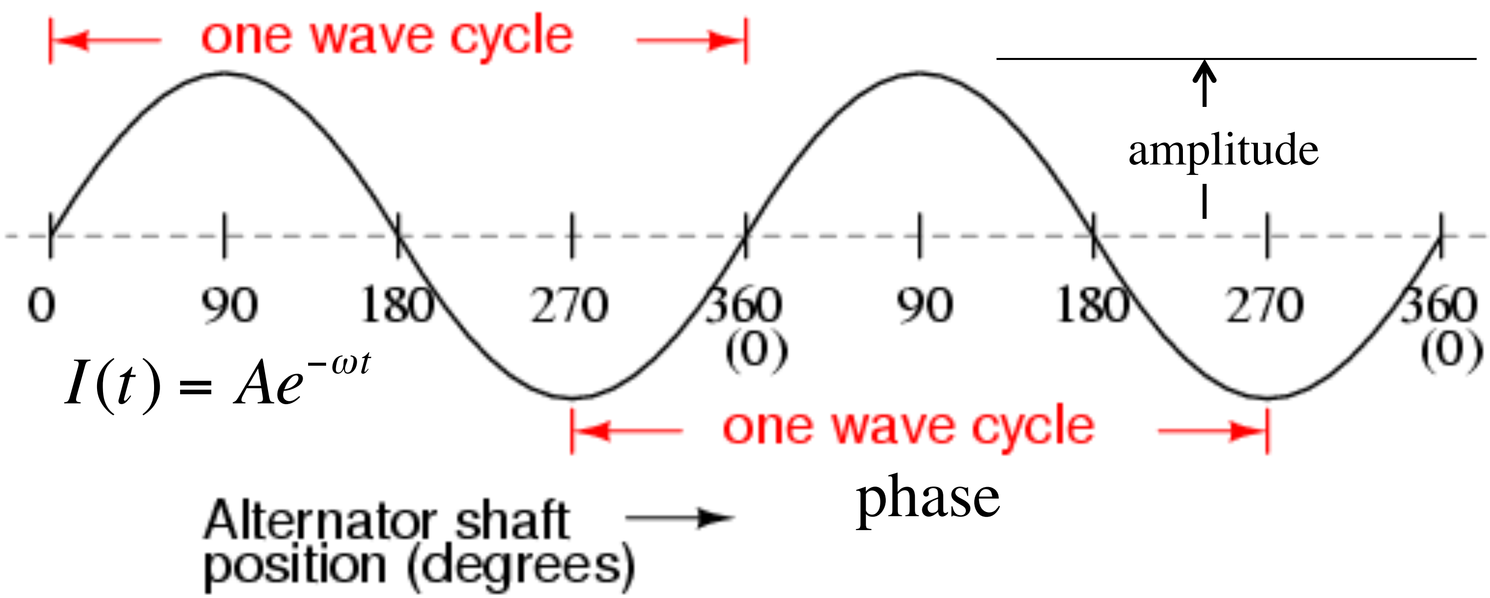
$$I(t) = Ae^{-\omega t}$$

phase

Alternating Current Waveform (frequency)

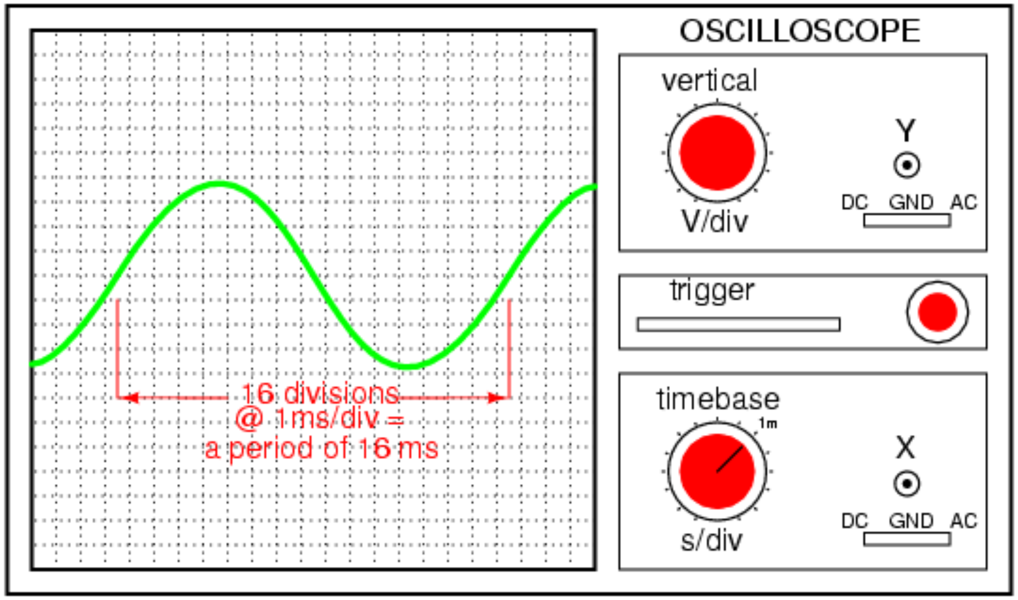
• In the United States, the standard power-line frequency is 60 Hz, meaning that the AC voltage oscillates at a rate of 60 complete back-and-forth cycles every second.

In Europe, where the power system frequency is 50 Hz, the AC voltage only completes 50 cycles every second.



$$I(t) = Ae^{-\omega t}$$

Alternating Current Waveform (View in Scope)

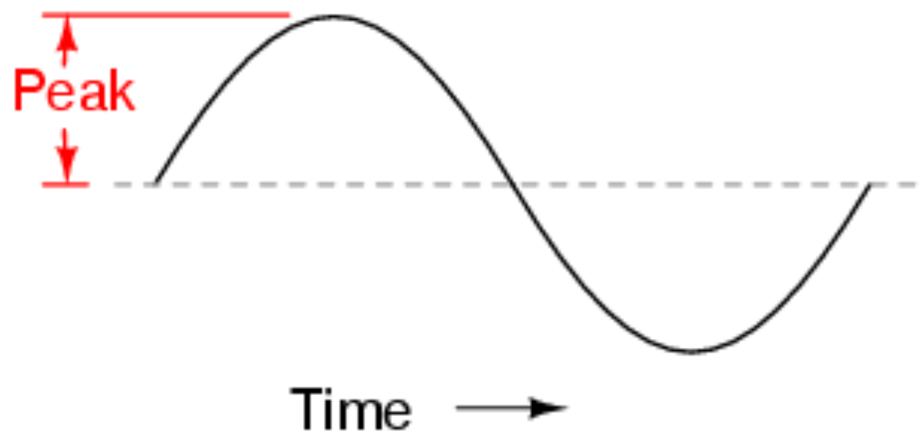


$$\text{Frequency} = \frac{1}{\text{period}} = \frac{1}{16\text{ ms}} = 62.5\text{ Hz}$$

$$\text{Frequency in Hertz} = \frac{1}{\text{Period in seconds}}$$

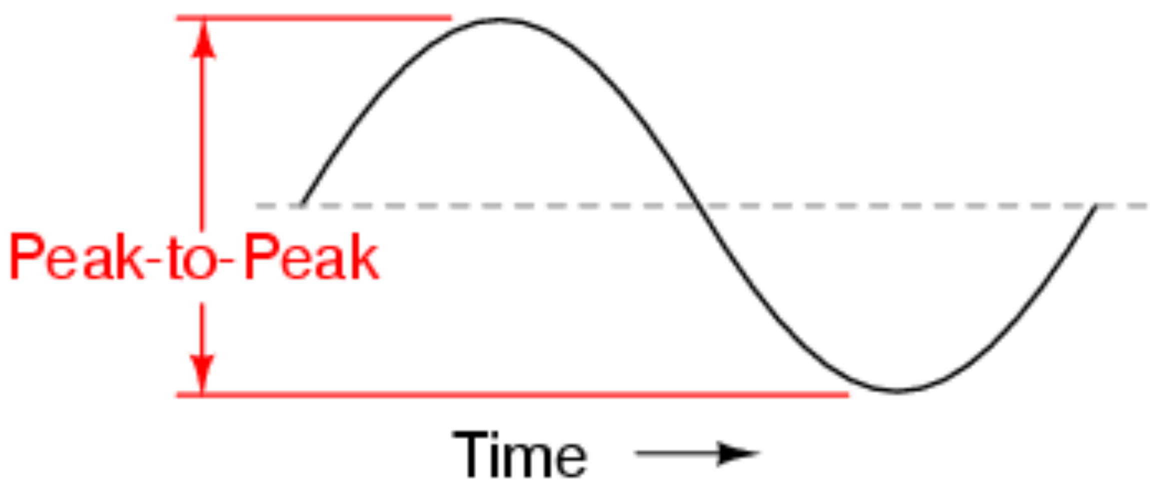
Alternating Current Waveform (Amplitude)

• One way to express the intensity, or magnitude (also called the *amplitude*), of an AC quantity is to measure its peak height on a waveform graph. This is known as the *peak* or *crest* value of an AC waveform:



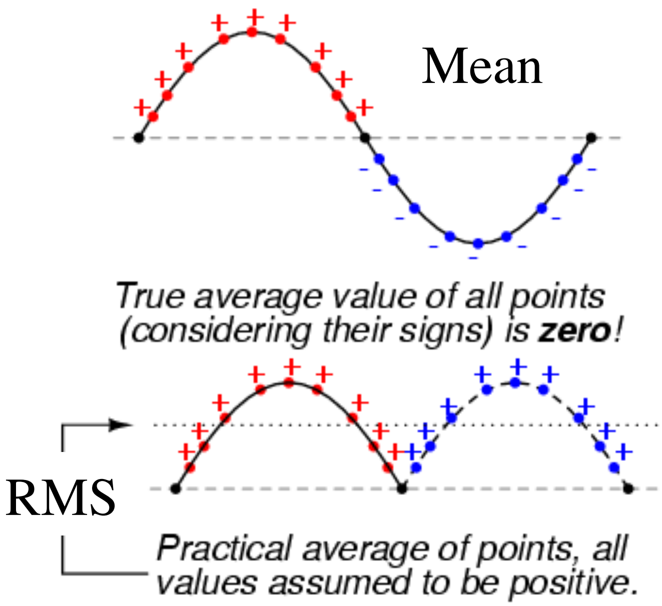
Alternating Current Waveform (Peak-to-Peak)

- Another way is to measure the total height between opposite peaks. This is known as the *peak-to-peak* (P-P) value of an AC waveform:



Alternating Current Waveform (RMS) (1)

- The Energy delivered over a single oscillation is know as the "Root Mean Square" (RMS) value



$$\int_0^T \mathrm{Sin}[\omega * t]^2\, dt =$$

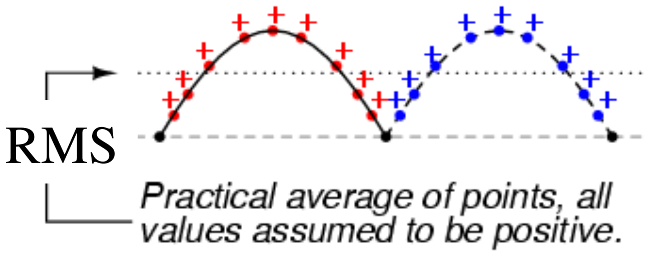
$$\frac{T}{2} - \frac{\mathrm{Sin}[2\,T\,\omega]}{4\,\omega} = \frac{T}{2}$$

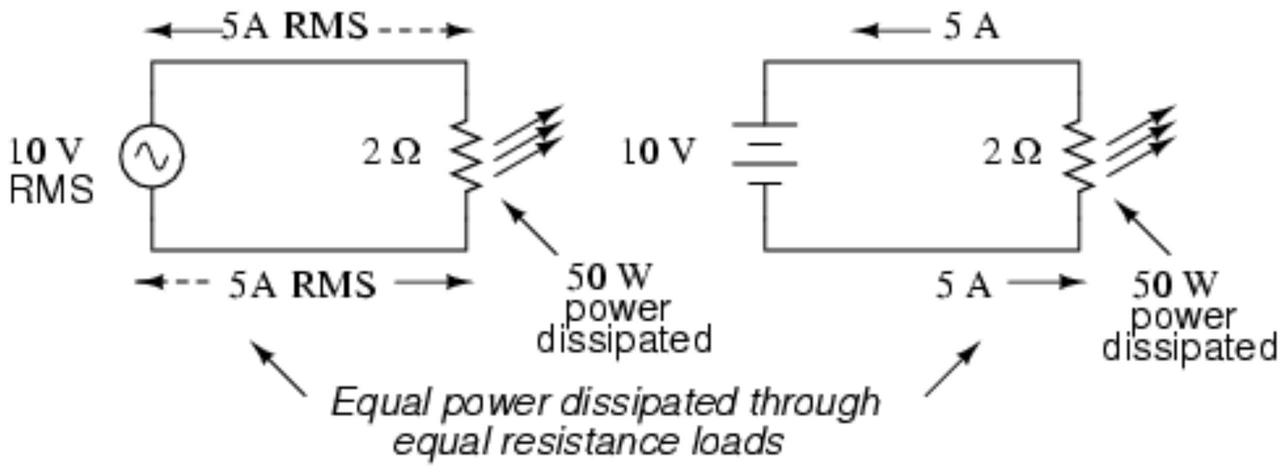
$$\omega \to 2\,\pi\,/\,T$$

$$RMS = \frac{1}{T}\sqrt{\int_0^T \left[\left(A\sin\omega t\right)^2\right]dt}$$

$$\boxed{\rightarrow RMS = A\frac{\sqrt{2}}{2}}$$

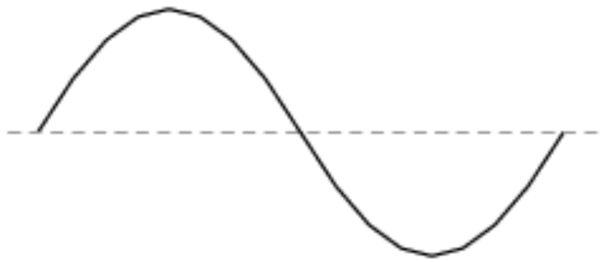
Alternating Current Waveform (RMS) (2)



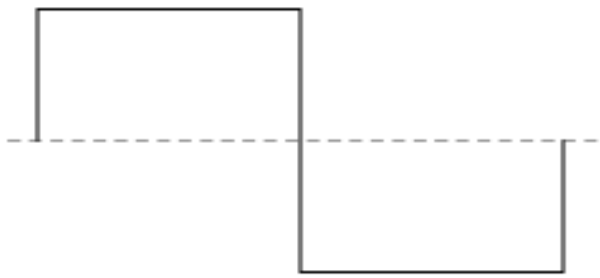


$$RMS = \frac{1}{T}\sqrt{\int_0^T \left[\left(A\sin\omega t\right)^2\right]dt} \qquad \boxed{\rightarrow RMS = A\frac{\sqrt{2}}{2}}$$

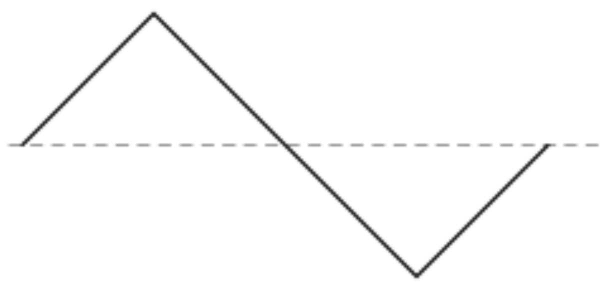
Amplitudes for Various Waveforms



RMS = 0.707 (Peak)
AVG = 0.637 (Peak)
P-P = 2 (Peak)

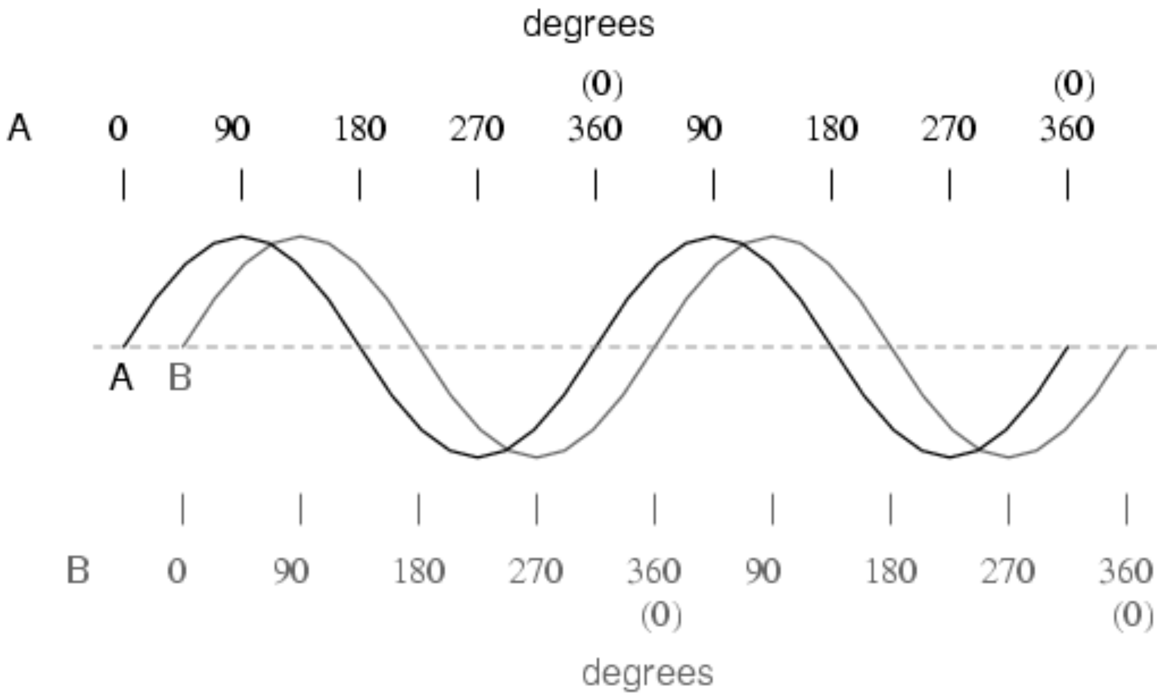


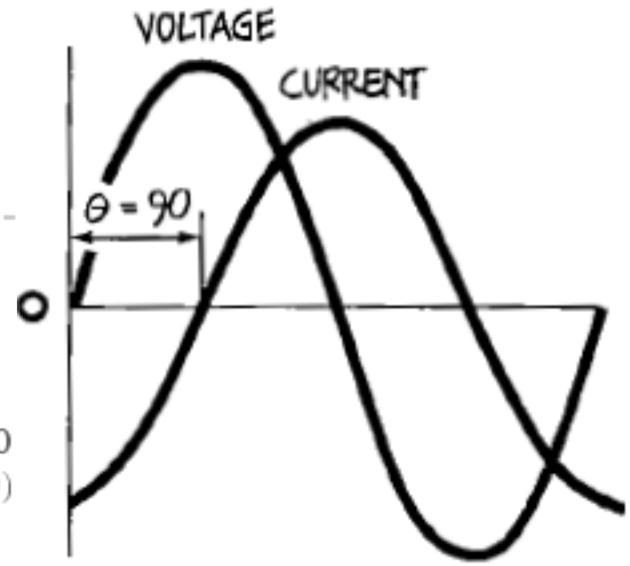
RMS = Peak
AVG = Peak
P-P = 2 (Peak)



RMS = 0.577 (Peak)
AVG = 0.5 (Peak)
P-P = 2 (Peak)

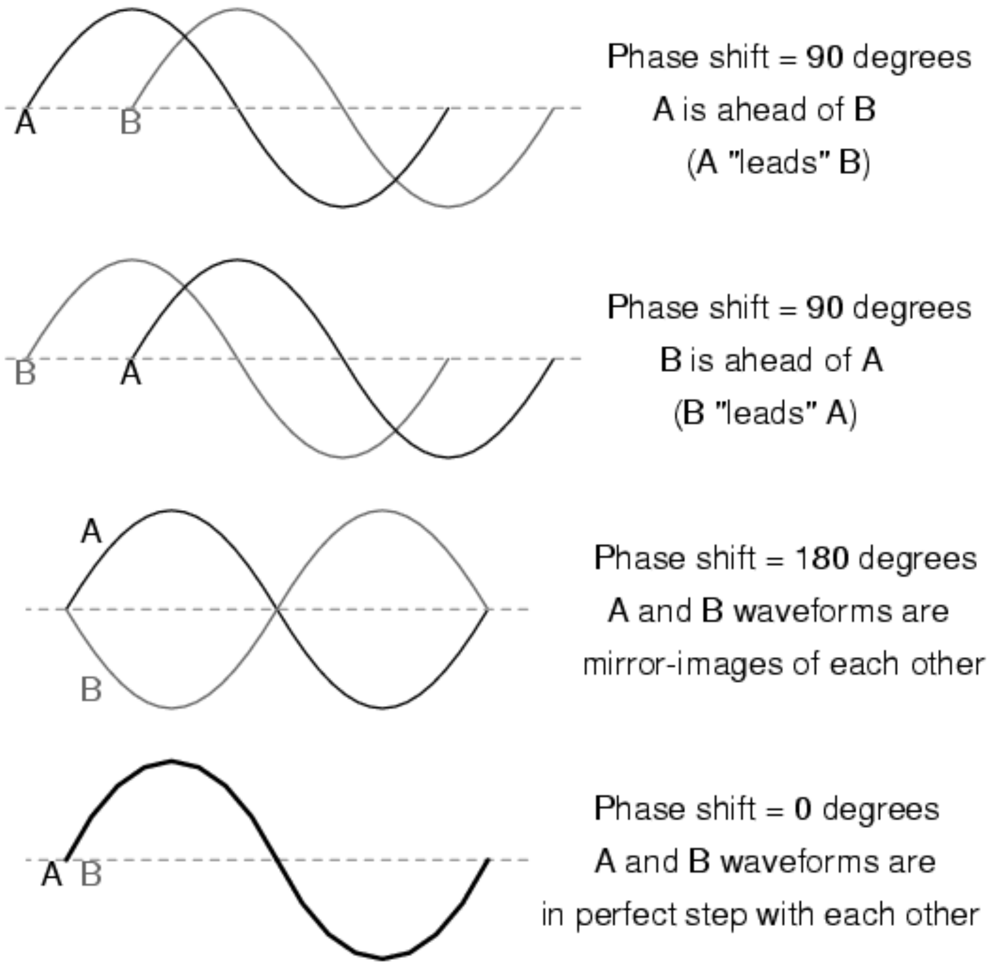
AC Waveform Phase Angle (1)





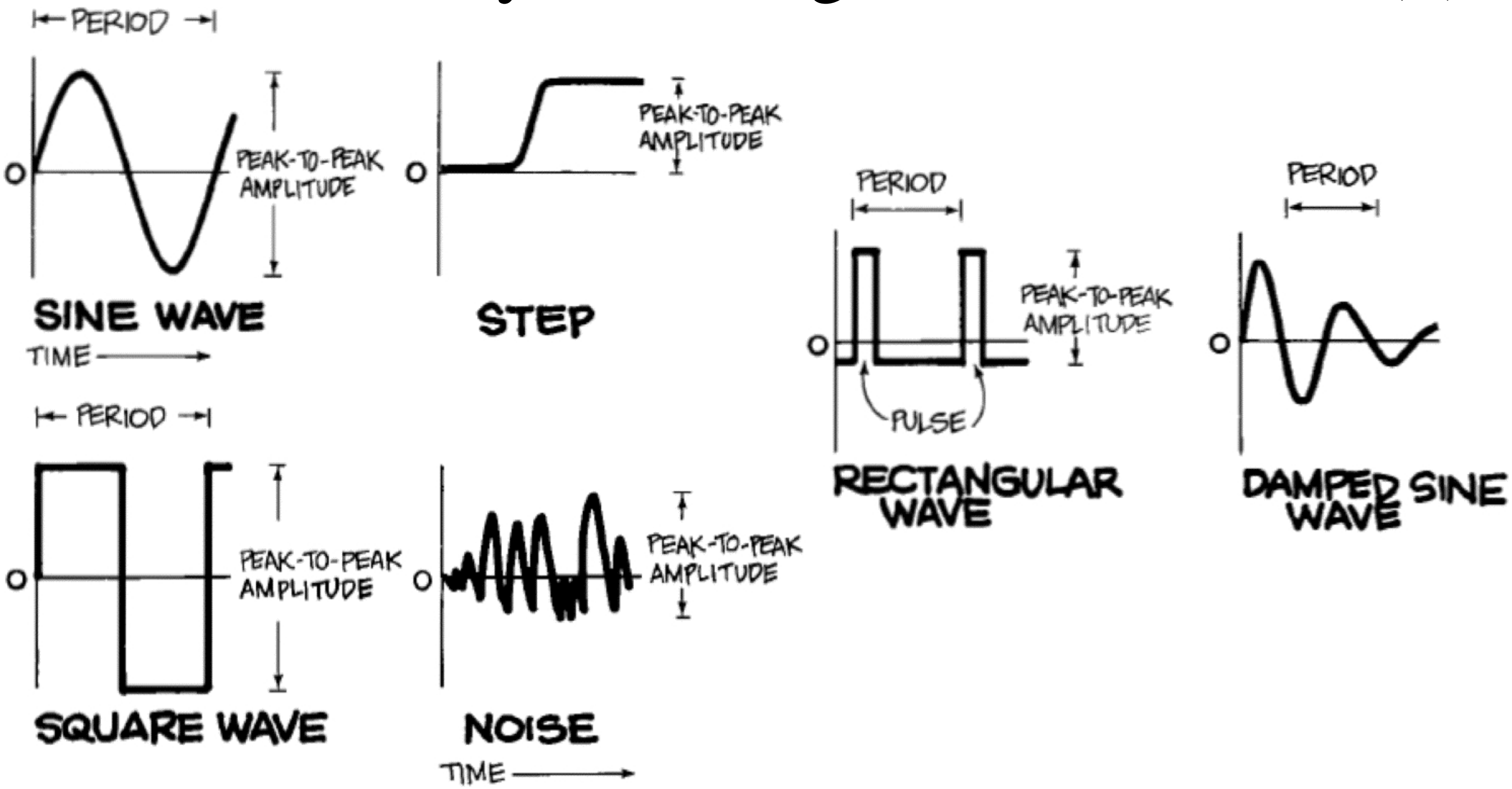
• The two waves shown above (A versus B) are of the same amplitude and frequency, but they are out of step with each other. In technical terms, this is called a *phase shift*.

AC Waveform Phase Angle (2)



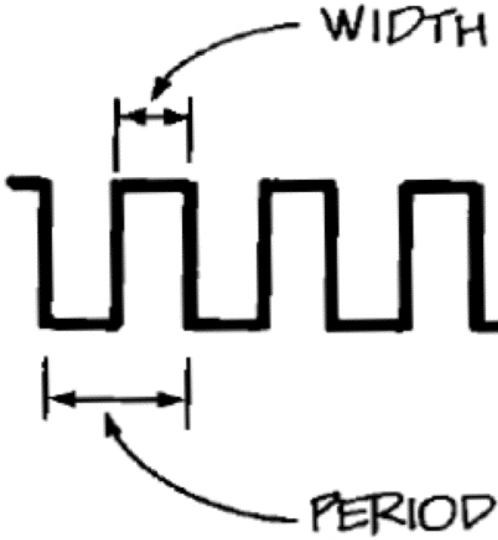
- Phase Shift Examples

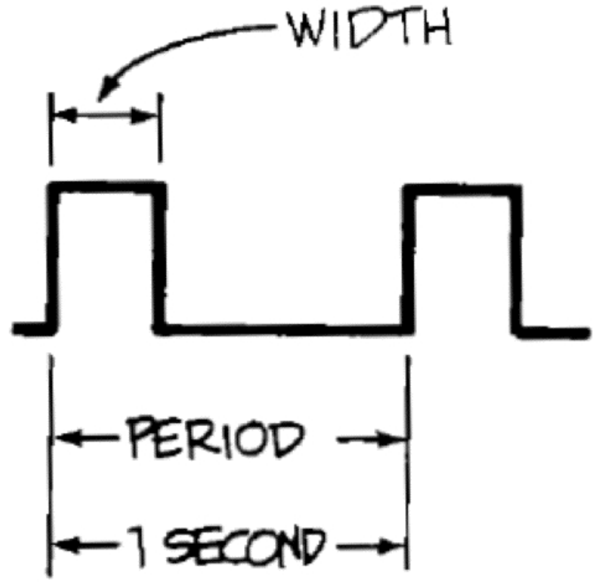
General Dynamic Signals, Definitions (1)



PERIOD IS THE TIME REQUIRED FOR ONE CYCLE OF A SIGNAL if the signal repeats itself. Period is a parameter whether the signal is symmetrically shaped like the sine and square waves above, or whether it has a more complex and asymmetrical shape like the rectangular wave and damped sine wave. Period is always expressed in units of time. Naturally, one-time signals like the step or uncorrelated signals (without a time relation) like noise have no period.

General Waveform Definitions (2)





DUTY CYCLE = 50%

WIDTH/PERIOD X 100 = N%

DUTY FACTOR = .3

DUTY CYCLE = 30%

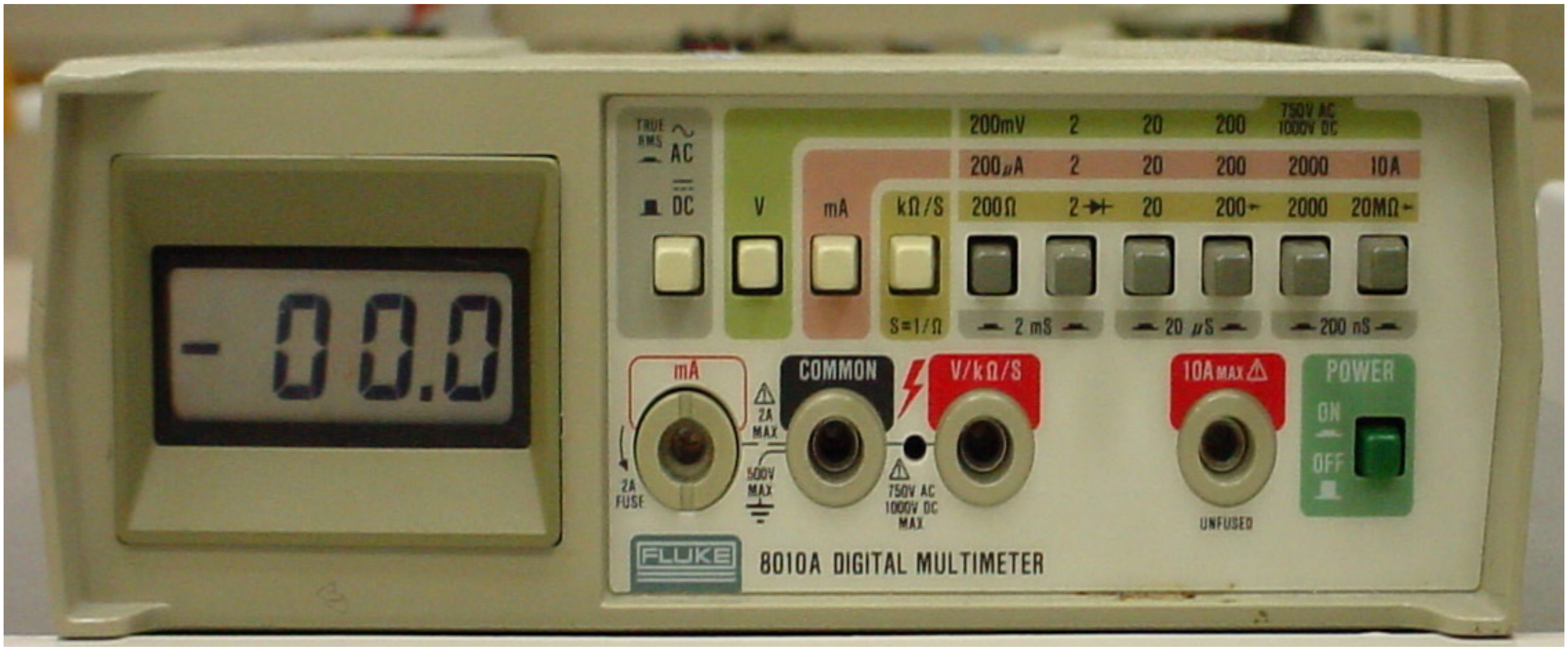
REPETITION RATE = 1/SECOND

DUTY CYCLE, DUTY FACTOR, AND REPETITION RATE are parameters of all rectangular waves.

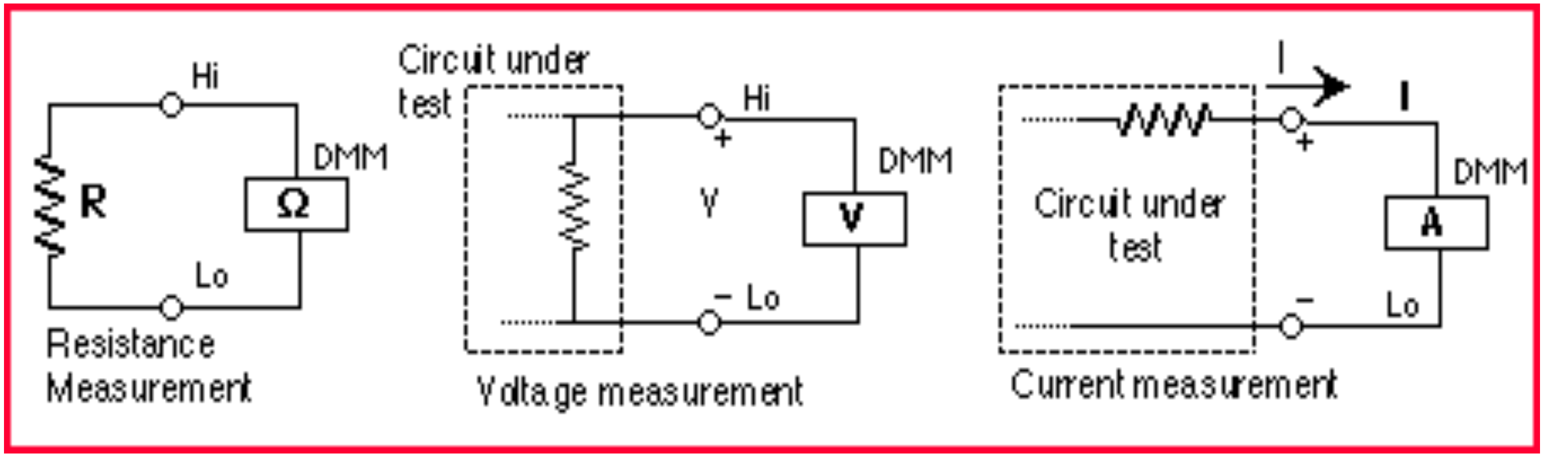
Duty cycle

is the ratio of pulse width to signal period expressed as a percentage.

VOLTMETERS


-00.0
TRUE RMS
AC
DC
V
mA
kΩ/S
200mV 2 20 200 750V AC 1000V DC
200μA 2 20 200 2000 10A
200Ω 2 20 200 2000 20MΩ
S=1/Ω
2 mS
20 μS
200 nS
mA
2A MAX
2A FUSE
500V MAX
COMMON
V/kΩ/S
750V AC 1000V DC MAX
10A MAX
UNFUSED
POWER
ON
OFF
FLUKE
8010A DIGITAL MULTIMETER

Voltage/Current Measurements (Revisited)



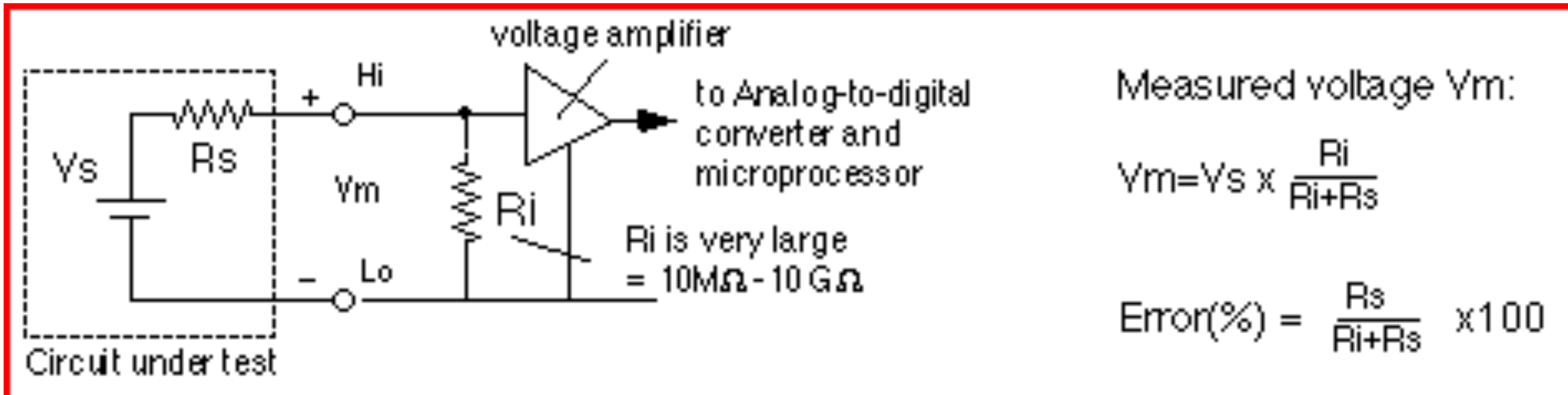
• Voltages are measured across ***(e.g., in parallel with)*** a Component

• Currents are measured through ***(e.g. in serial with)*** a component.

• *Resistance measurements must be made with NO POWER applied to the measured device.*

• *Make certain that the DVM is NOT set to measure resistance when wired to measure voltage or current.*

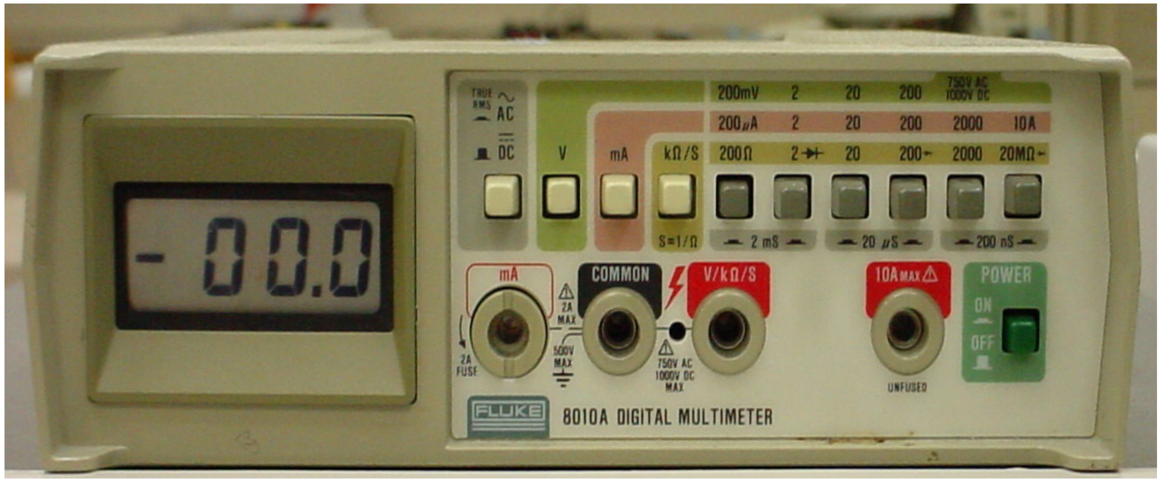
DVM as a voltage measurement device



• An ideal voltmeter has an infinite input resistance so that it will not draw any current from the circuit under testing.

As a result, one has a voltage divider that will cause the voltage Vm one sees at the input of the voltmeter to be slightly different from the actual voltage VS one wants to measure. Our DVM's have relatively large input resistances (~ 10Mohm) (depending on the selected voltage range) so that the error will be small as long as Rs << Ri.

Fluke 8010A Digital Volt Meter (1)

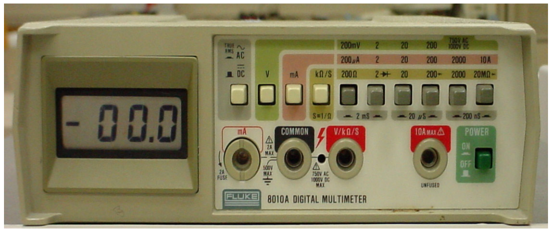


Digital Voltmeter (DVM): The digital voltmeter measures both *Alternating Current* (AC) and *Direct Current* (DC) *Voltage*, *current* , and component *resistance*.

• This is an older product no longer supported by Fluke® … so be careful …. ***its irreplaceable!***

The display on the meter is called a "three and a half" digit display, with the first digit capable of displaying +1, 0, or -1 (counts for half a digit), plus three additional digits.

Fluke Digital Volt Meter (2)



- Fluke 8010A digital Voltmeter, can measure AC or DC voltage, current, resistance, or conductivity.

- **Measuring Voltage**

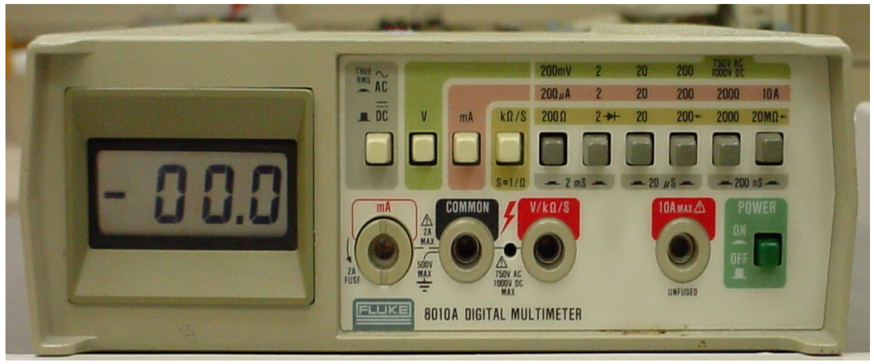
  Connect the COMMON input (a black lead) to the circuit's ground, and connect the V/k/S input (a red lead) to the voltage to measure.

- **Measuring Current**

  Connect the COMMON input and either the mA or the 10A max input in series with the wire whose current you wish to measure.

  Requires disconnecting the wire, often after the circuit is powered down.

Fluke Digital Volt Meter (3)



• Measuring Resistance or Conductance

With the circuit power off, connect the COMMON (black) and V/k/S (red) leads across the resistive element. For accurate measurement, the element usually has to be removed from the circuit, although simple continuity checking (determining if a wire is connected) can be done in-circuit.

The maximum measured range is selected by front panel buttons. Make certain the AC/DC (alternating current/direct current) button corresponds to the proper type of waveform for your measurement, since the measurement of AC and DC voltages is fundamentally different.

HP 34401A Digital Volt Meter (1)

- Several orders of magnitude more Precise than Fluke 8010A Meter

HP Digital Volt Meter (2)

• HP34401digital is a high performance instrument FOR measuring resistance, DC and AC voltage, current, AND signal frequency.

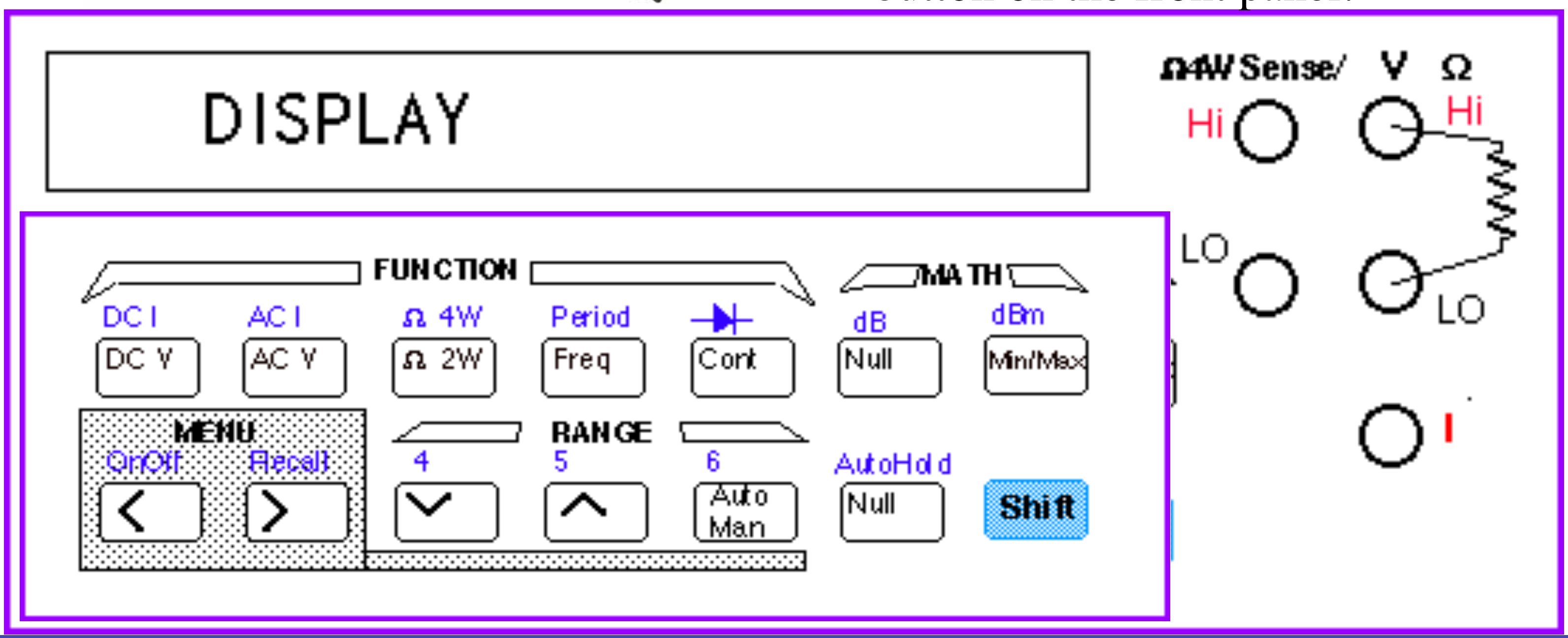
• HP34401A has a built-in microprocessor, memory and other features such as built-in math functions, recording and storing up to 512 readings, giving the maximum, minimum and average of the readings. In addition, it can be remotely programmed using the SCPI (Standard Commands for Programmable Instruments) language and read by computer via a General Purpose Interface Board (GPIB) port.

• For this lab we'll exercise the voltage functions

HP Digital Volt Meter (3)

- To measure a voltage, connect the nodes over which one wants to measure the voltage between the HI and LO input terminals of the DVM.

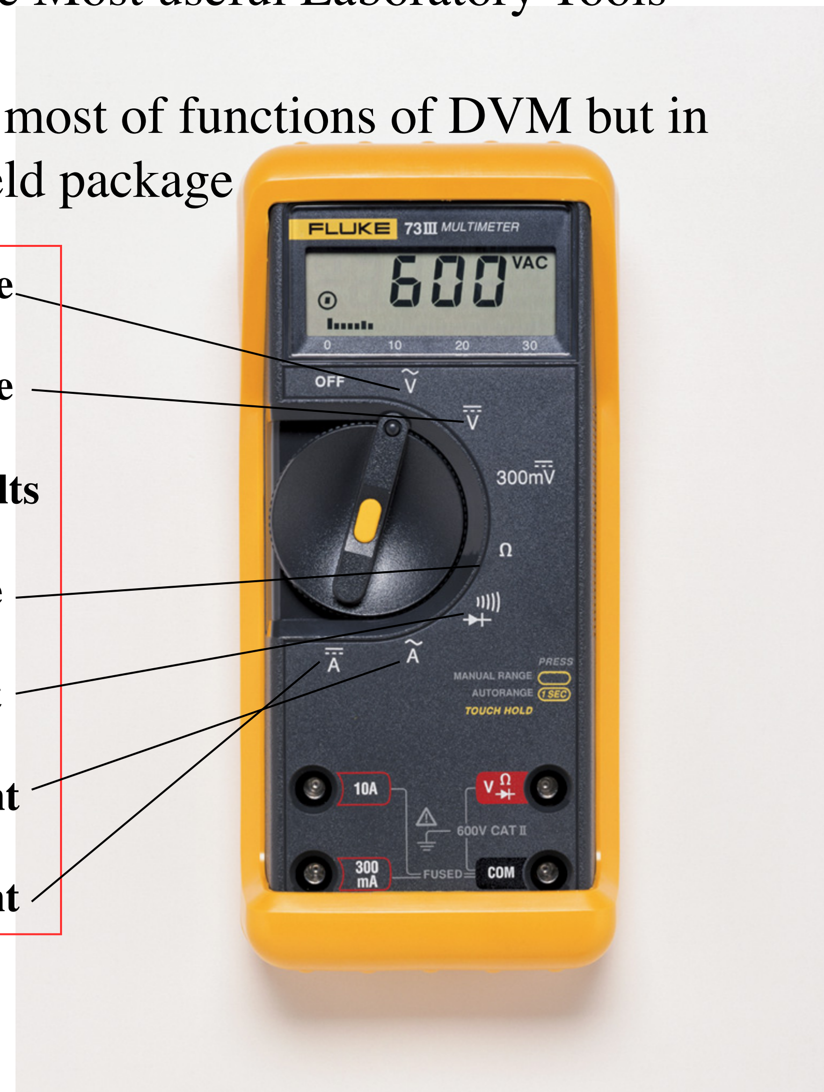
- In order to activate the DVM for DC measurements you have to select the DC Voltage function by pushing the **DC V** button on the front panel.



Hand Held MultiMeter (1)

- One of the Most useful Laboratory Tools
- Performs most of functions of DVM but in a Hand Held package

Ac/Dc Selector



AC voltage

DC voltage

DC milivolts

Resistance

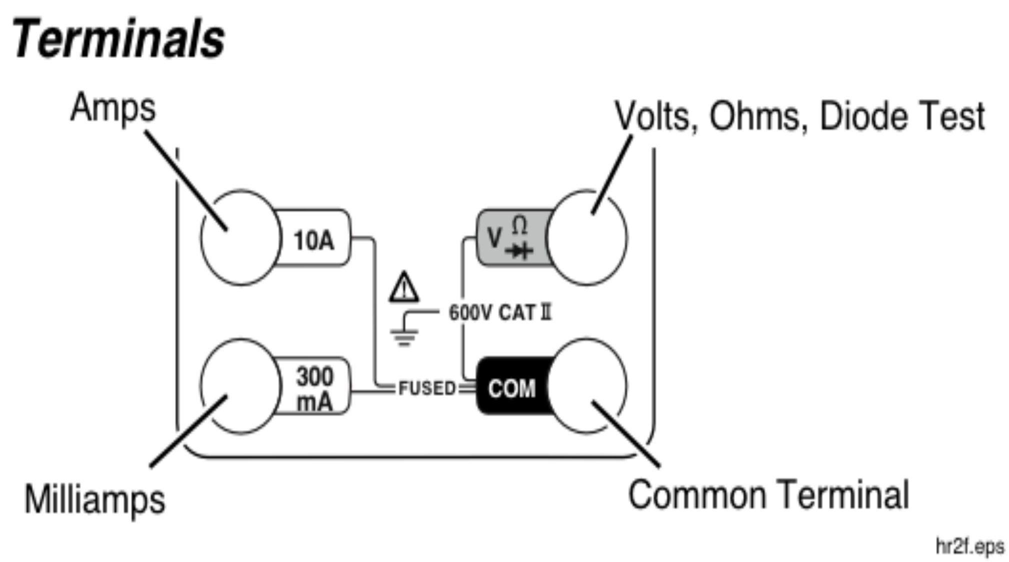
Diode Test

AC current

DC current

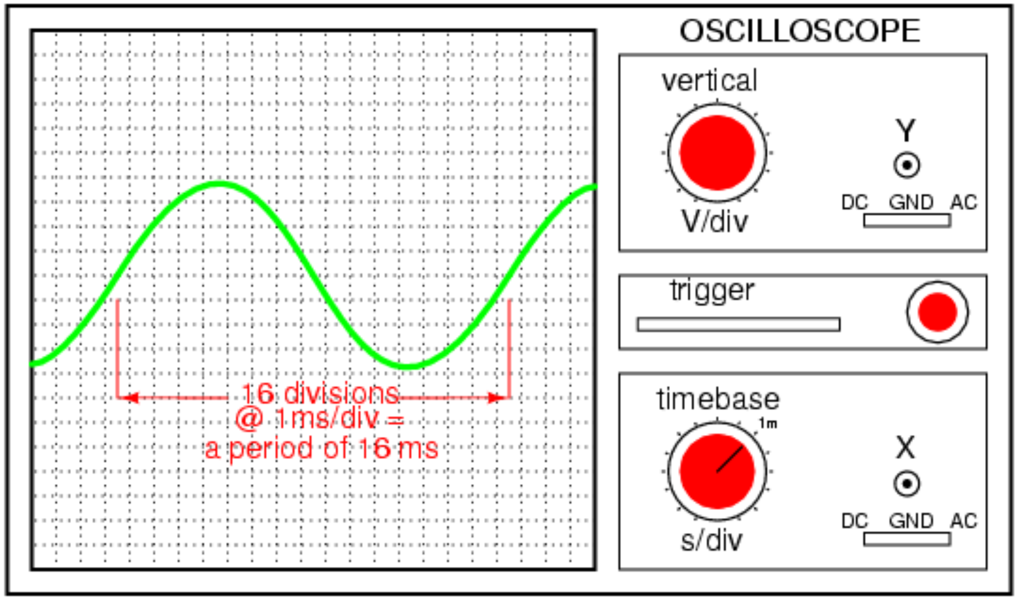
Hand Held MultiMeter (2)

Pay attention to probe connections
Setting device on Voltage with current probe connection and vice-versa can ruin DMM



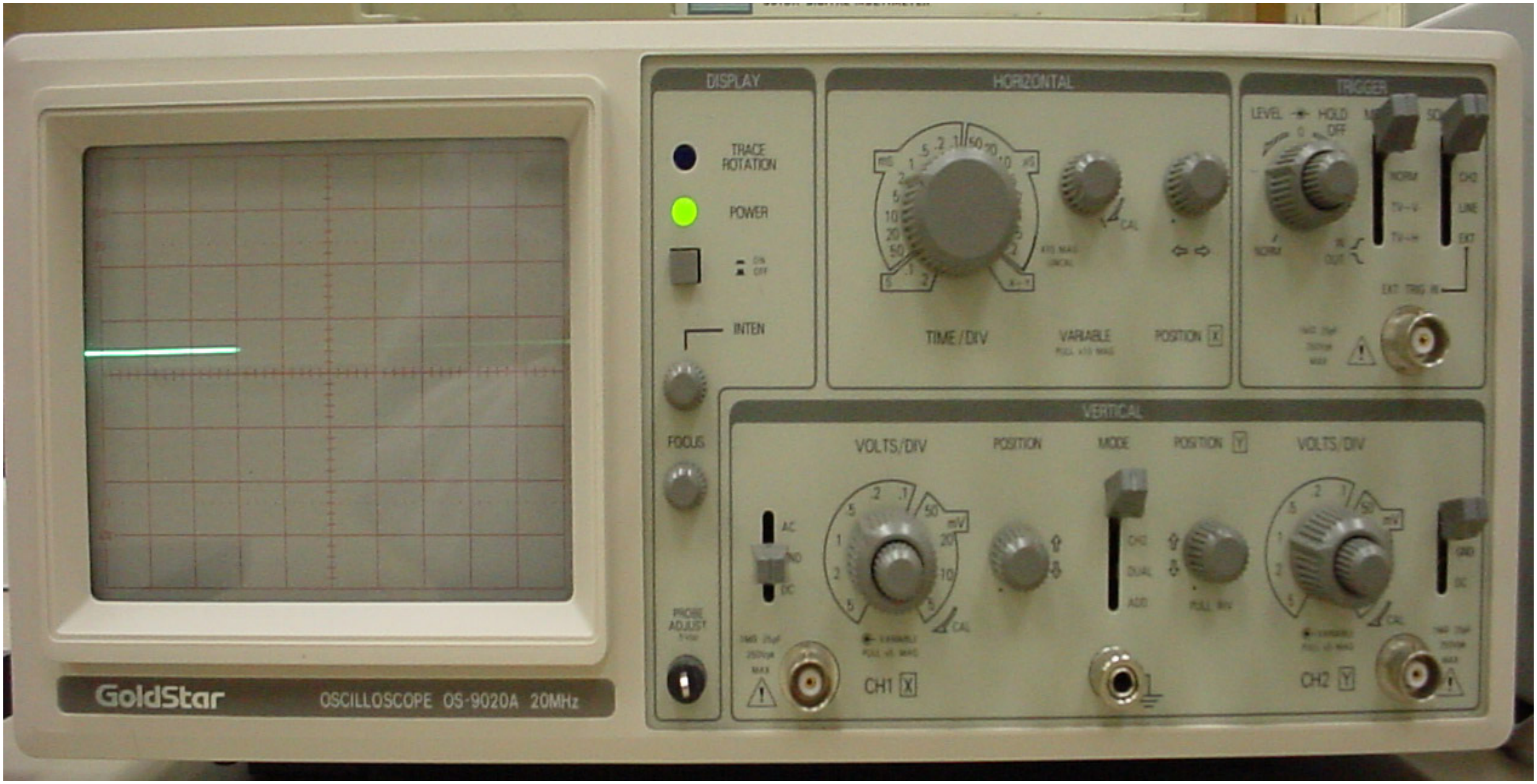
See Specifications for overload protection.

OSCILLOSCOPES



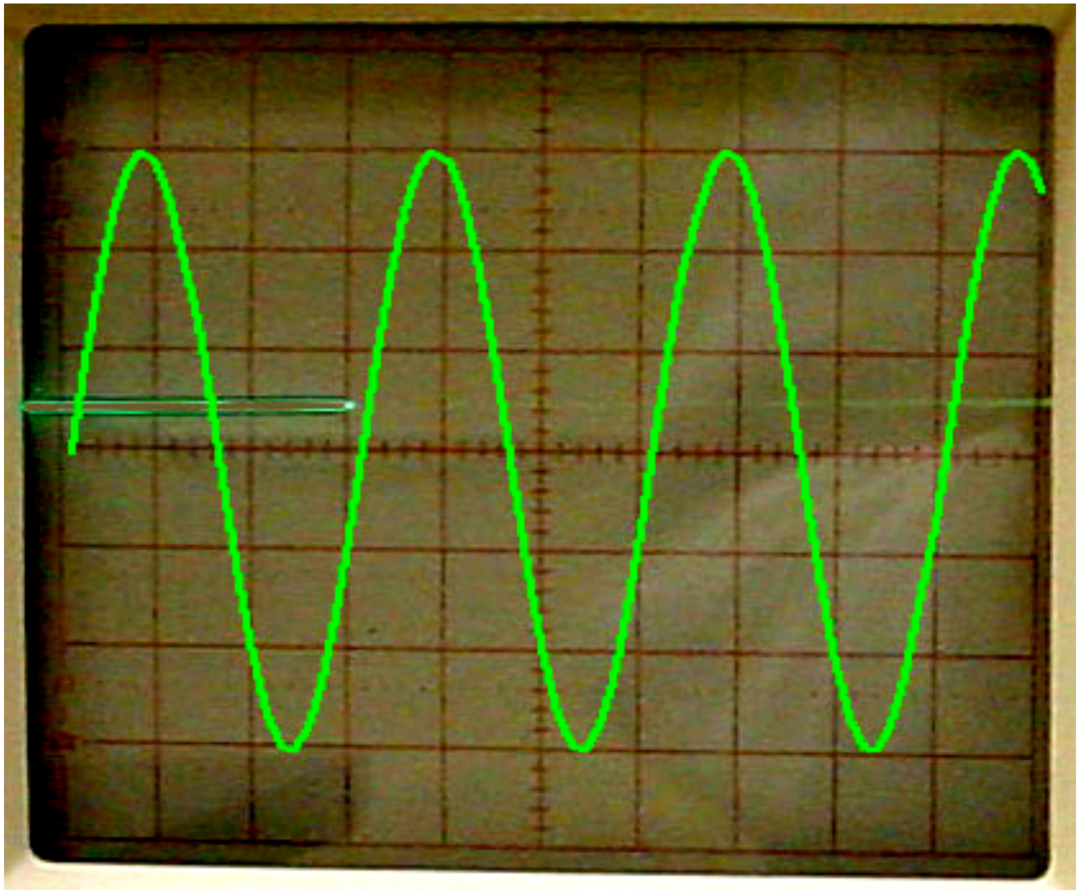
$$\text{Frequency in Hertz} = \frac{1}{\text{Period in seconds}}$$

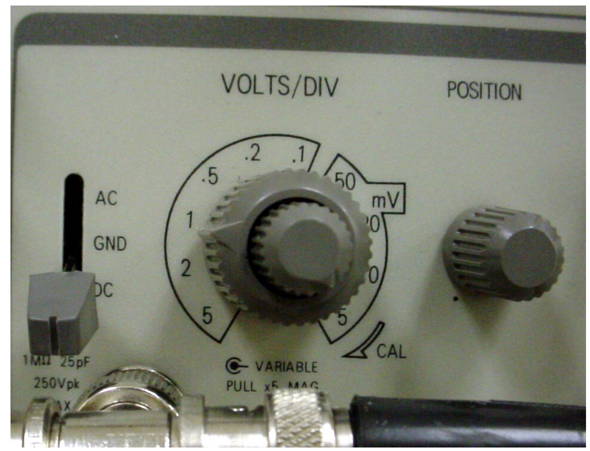
Oscilloscope Primer (1)



GoldStar OS 9020 Analog Oscilloscope

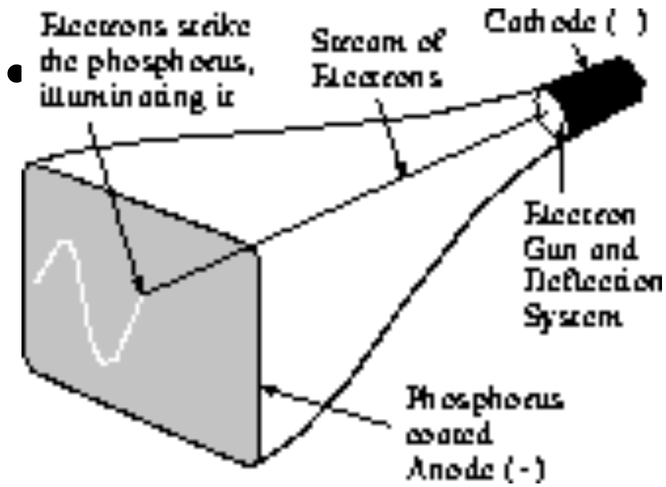
Oscilloscope Primer (2)





- **Detailed Primer on Scope Posted on Webpage (Lab 4)**

Oscilloscope Primer (3)



- Oscilloscopes display very high-speed periodic events.

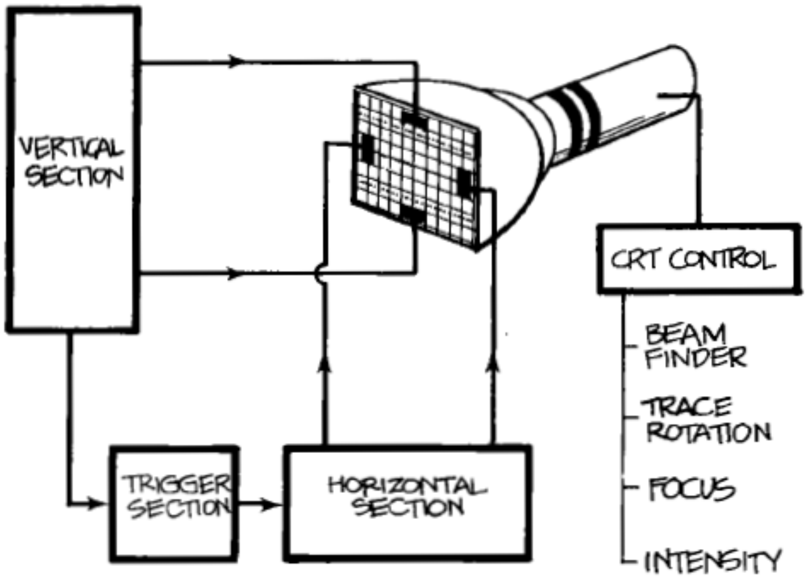
- Think of them as “black boxes” that graph voltage versus time.

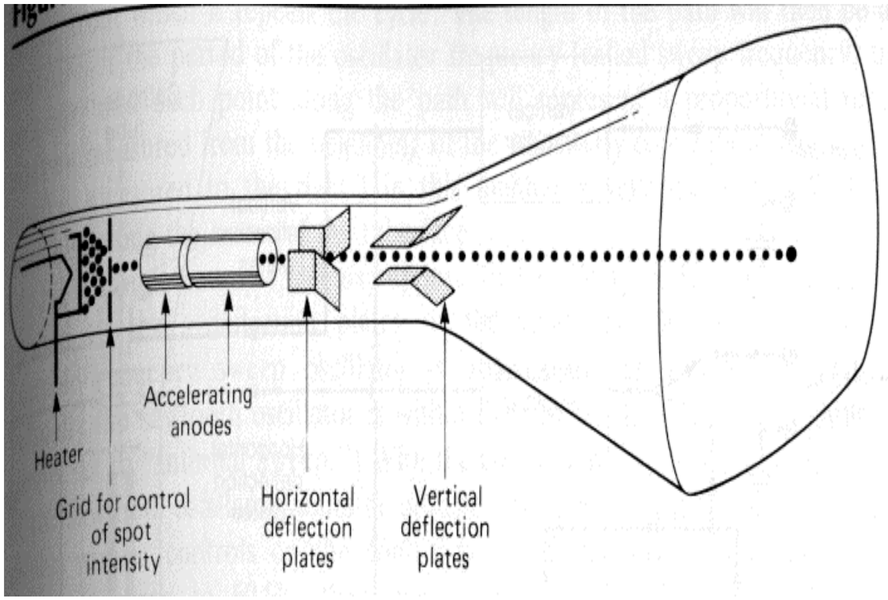
- Oscilloscope's major components:

  Cathode ray tube (CRT), similar to that in a television. A large voltage is placed across anode and cathode, causing electrons to fly from the negatively-charged cathode, through a vacuum, and smash into the positively-charged anode, illuminating a spot on its phosphorus coating.

  Bright spot fades quickly, so for an image to appear stable, it must be refreshed at a high rate (many times /second.)

Oscilloscope Primer (4)





• To display a repeating waveform, the oscilloscope periodically ``sweeps'' the beam from left to right, vertically deflecting the beam proportional to the input voltage.

• The result is a graph with time increasing horizontally to the right, voltage increasing in the (up)vertical direction

Oscilloscope Primer (5)

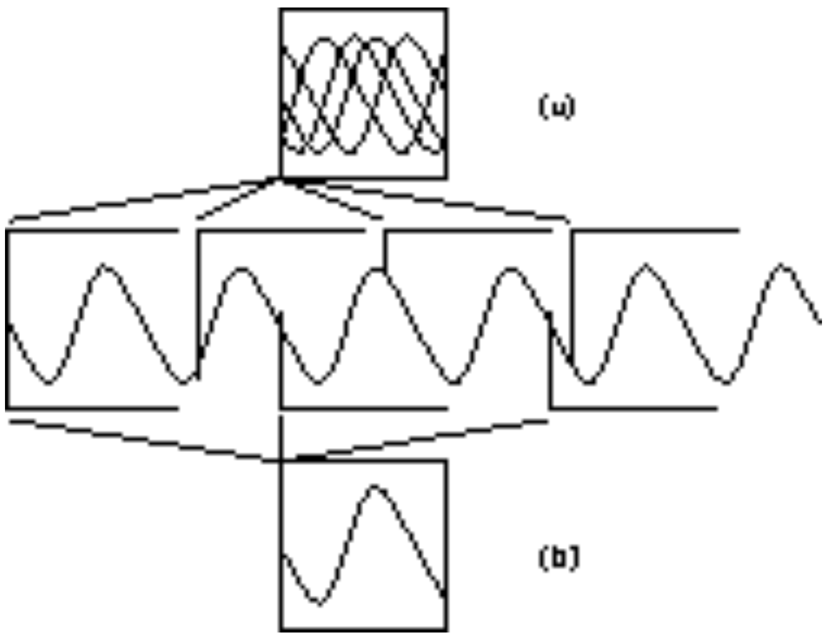
• Starting sweep at proper time is necessary for a maintaining a stable image.

• Image (a) shows effect of choosing wrong phasing: many segments of waveform are superimposed, resulting in wave overlap .. Essentially unreadable.

• If timing is phased at some multiple of the period of the waveform,traces superimpose to give a single, stable waveform trace, as shown image (b)

• Most oscilloscopes allow user to set a voltage and slope (rising or falling) f or the trigger. … in Image (2) trigger is voltage halfway between PEAKS, with a falling slope.

• WORKS well for simple waveforms. For complex waveforms, variable holdoff sets time between end of a sweep and when starts looking for trigger.



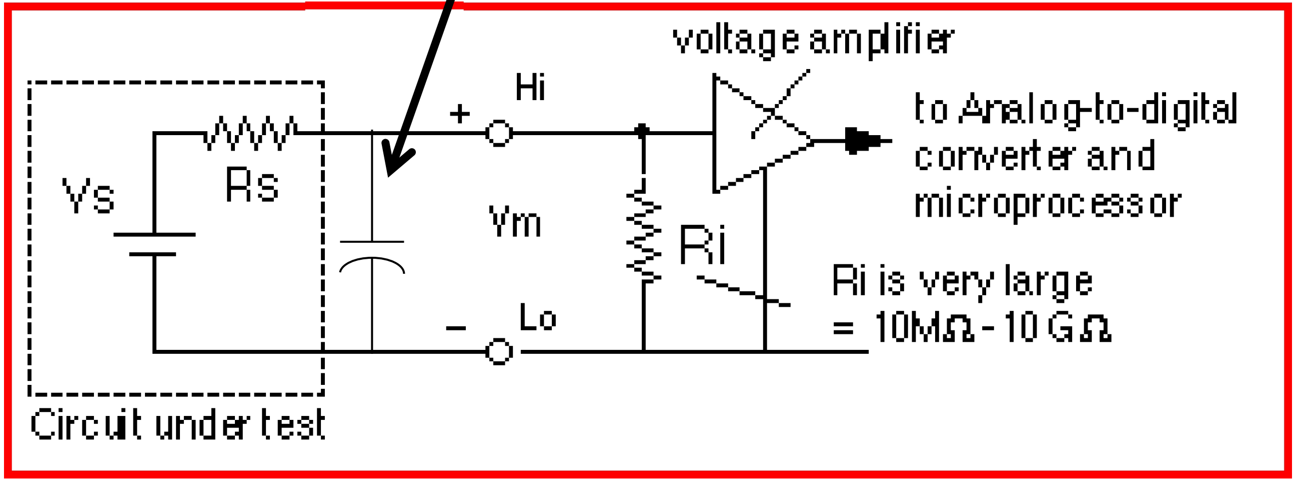
Oscilloscope Primer (6)

- ***A/C versus D/C coupling on input***

DC (the abbreviation normally stands for *direct current)* input coupling lets you see all of an input signal. AC *(alternating current)* coupling blocks the constant signal components and permits only the alternating components of the input signal to reach the channel.

AC coupling is handy when the entire signal (alternating plus constant components) might be too large for the VOLTS/DIV switch settings you want.

- Capacitance between terminals



UtahState UNIVERSITY

Mechanical & Aerospace Engineering

Horizontal Scope Control

THE HORIZONTAL SYSTEM CONTROLS

1. Switch the VERTICAL MODE to CH 1 and the CH 1 VOLTS/DIV setting to 0.5 volt. Be sure your probe is connected to channel 1 and the PROBE ADJ jack. Turn on your scope and move the channel 1 input coupling lever to GND and center the signal on the screen with the POSITION control. Switch to AC coupling.

2. Now you can use the horizontal system of your scope to look at the probe adjustment signal. Move the waveform with the horizontal POSITION control until one rising edge of the waveform is lined up with the center vertical graticule. Examine the screen to see where the leading edge of the next pulse crosses the horizontal center line of the graticule. Count major and minor graticule markings along the center horizontal graticule and remember the number.

3. Change sweeps to 0.2 ms, line up a rising edge with the vertical graticule on the left edge of the screen and count to the next rising edge. Because the switch was changed from 0.5 to 0.2 ms, the waveform will look 2.5 times as long as before. Of course, the signal hasn't changed, only the scale factor.

4. In the middle of the SEC/DIV switch is the variable control; in its counterclockwise detent, the settings of the SEC/DIV switch are calibrated. Move the control from its detent to see its effect on the sweep speed. Note that now the cycles of the waveform are approximately two-and-a-half times smaller. Return the CAL control to its detent.

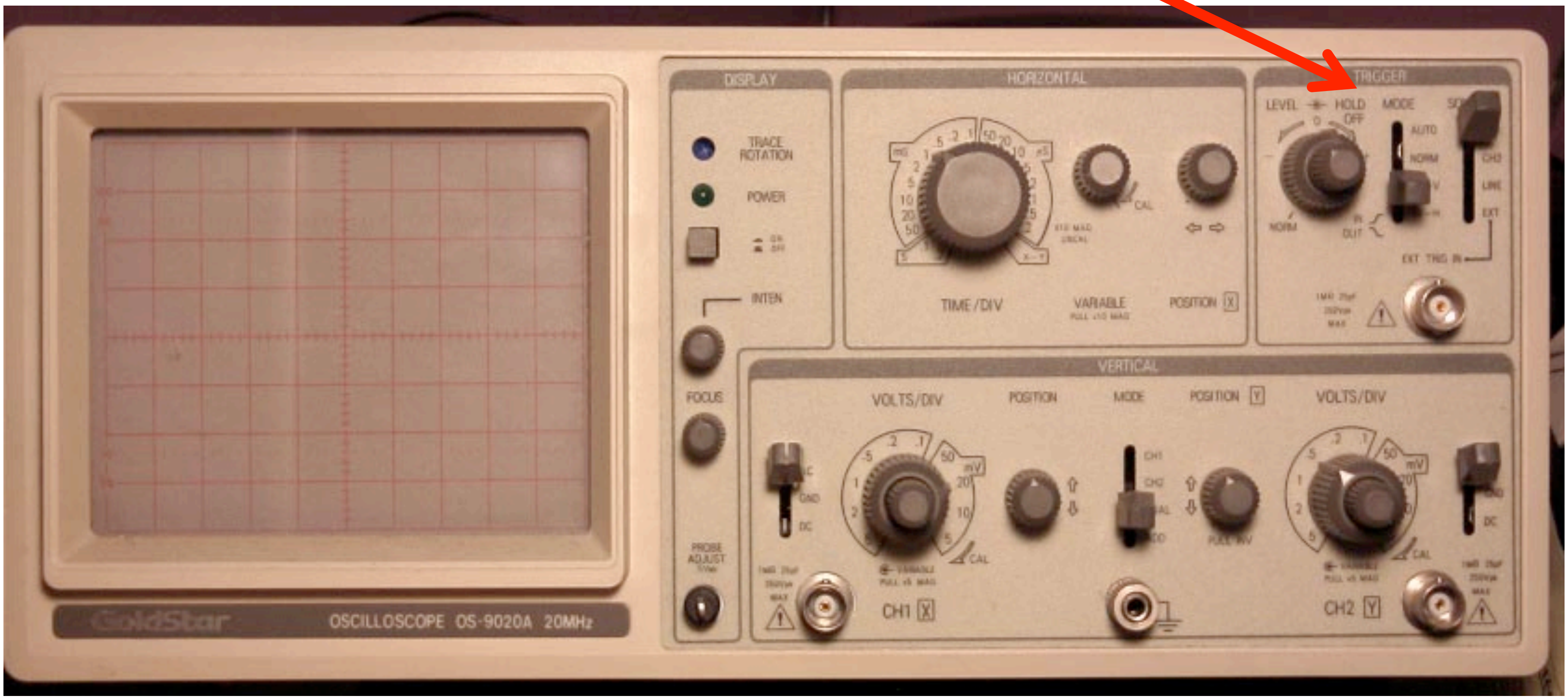
5. Move the SEC/DIV switch to 0.5 ms and then pull out the red CAL control. This gives you a 10X magnification of the sweep speed. In other words, every setting on the SEC/DIV switch will result in a sweep that's ten times faster; for example, the sweep now is 0.05 ms/division, not 0.5 ms.

6. While your scope is magnifying the probe adjustment signal, use the horizontal POSITION control. Its range is now magnified as well, and the combination of magnified signal and POSITION control gives you the ability to examine small parts of a waveform in great detail. Return your scope to its normal sweep speed range by pushing the CAL switch in.

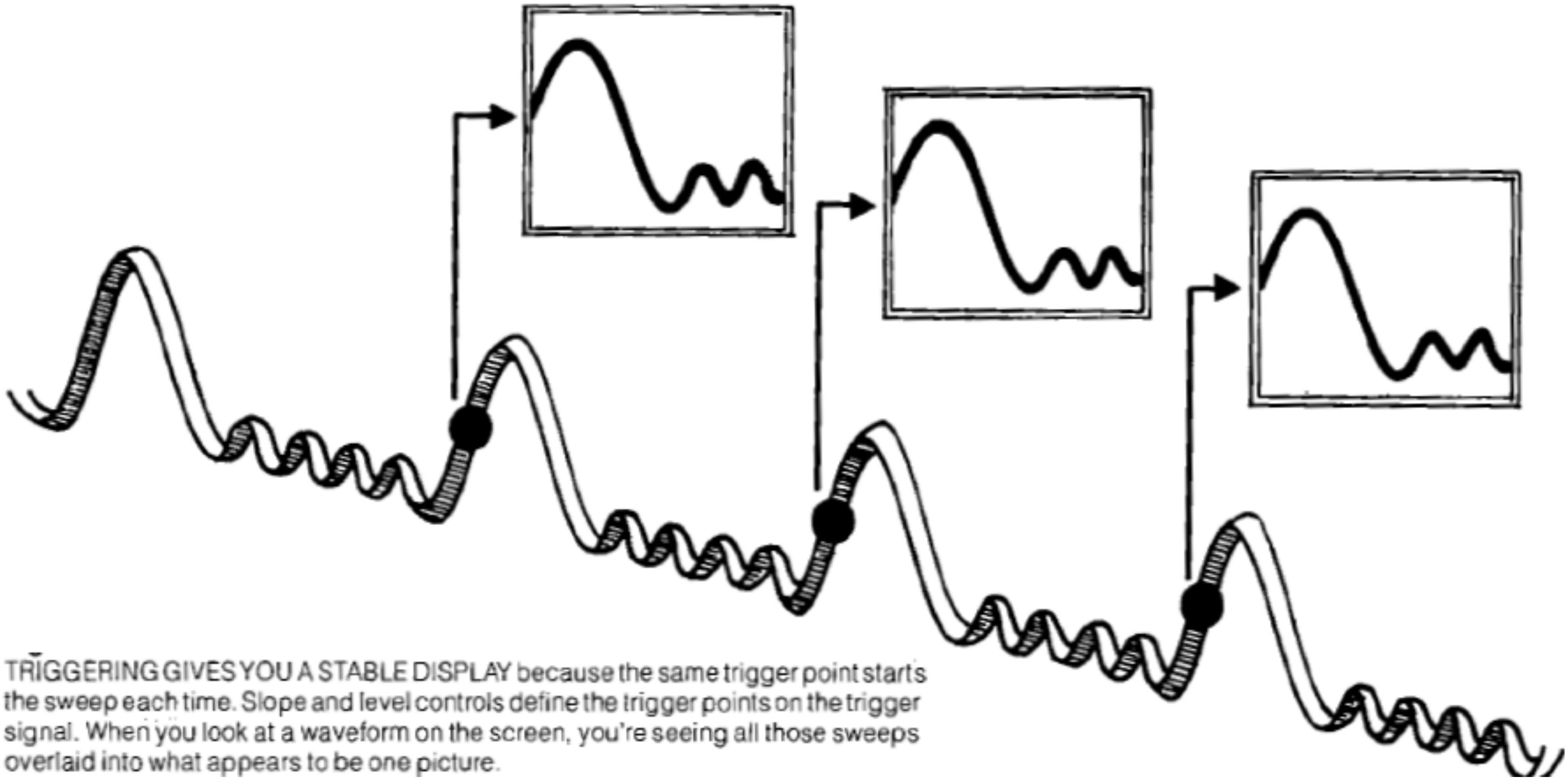
Scope Triggering

GoldStar OS-9020A Oscilloscope

Triggering Controls



Scope Triggering (1)



TRIGGERING GIVES YOU A STABLE DISPLAY because the same trigger point starts the sweep each time. Slope and level controls define the trigger points on the trigger signal. When you look at a waveform on the screen, you're seeing all those sweeps overlaid into what appears to be one picture.

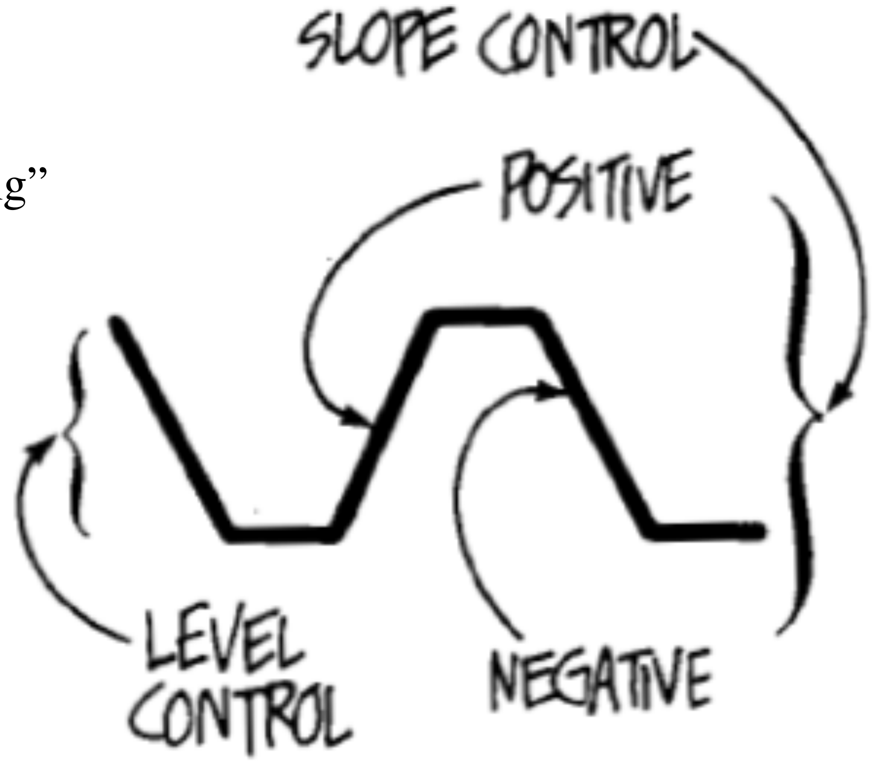
Scope Triggering (2)

- **Internal trigger**

".. Scope does the triggering"

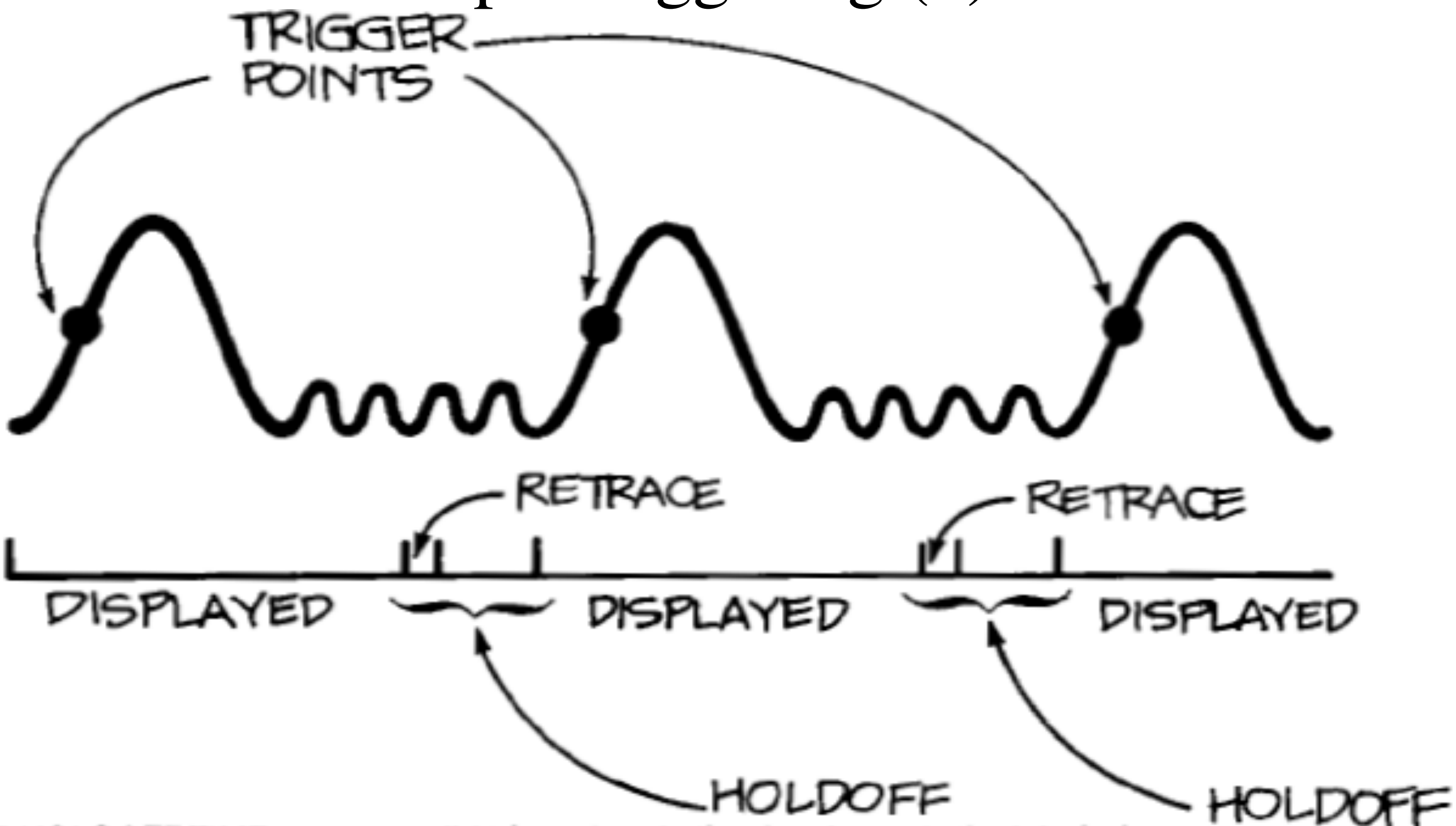
- **External Trigger**

… uses external signal



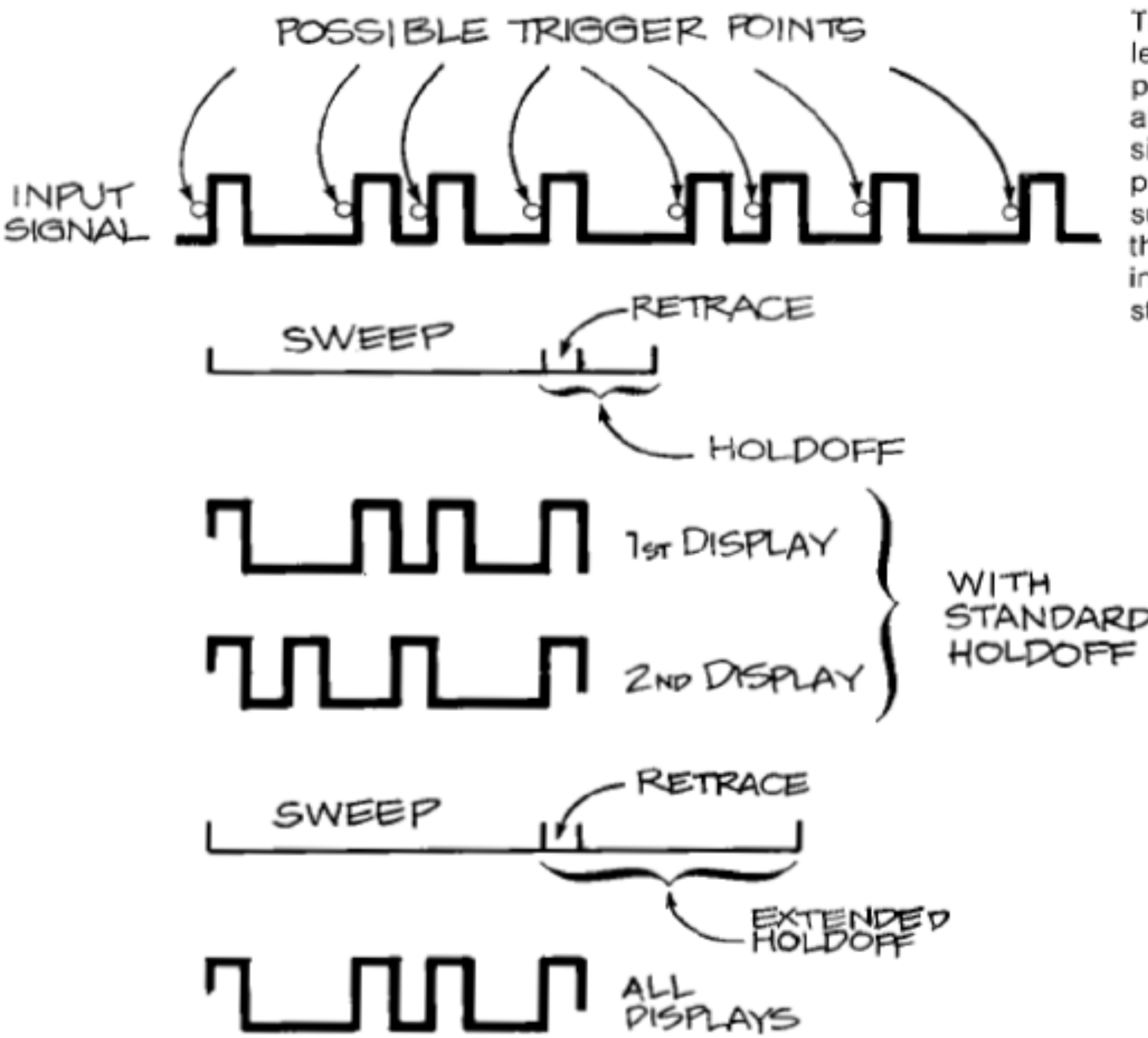
SLOPE AND LEVEL CONTROLS determine where on the trigger signal the trigger actually occurs. The SLOPE control specifies either a positive (also called the *rising* or *positive-going)* edge or on a negative *(falling* or *negative-going)* edge. The LEVEL control allows you to pick where on the selected edge the trigger event will take place.

Scope Triggering (3)



TRIGGER HOLDOFF TIME ensures valid triggering. In the drawing only the labeled points start the display because no trigger can be recognized during the sweep or the retrace and holdoff period. The retrace and holdoff times are necessary because the electron beam must be returned to the left side of the screen after the sweep, and because the sweep generator needs reset time.

Scope Triggering (4)



THE VARIABLE HOLDOFF CONTROL lets you make the scope ignore some potential trigger points. In the example, all the possible trigger points in the input signal would result in an unstable display. Changing the holdoff time to make sure that the trigger point appears on the same pulse in each repetition of the input signal is the only way to ensure a stable waveform.

- Especially Useful for non-Periodic signal .. Like serial Communications (RS-232)

Scope Triggering (5)

TRIGGER CONTROLS

1. *Move the trace to the right with the horizontal POSITION control until you can see the beginning of the signal (you'll probably have to increase the intensity to see the faster vertical part of the waveform). Watch the signal while you operate the SLOPE control. If you pick +, the* signal on the screen starts with a rising edge; the other SLOPE control position makes the scope trigger on a falling edge.

2. *Now move the LEVEL control back and forth through all its travel; you'll see the leading edge climb up and down the signal. The scope remains triggered because you are using the P-P AUTO setting.*

3. *Turn the MODE switch to NORM. Now when you use the LEVEL control to move the trigger point, you'll find places where the scope is untriggered. This is an illustration of the essential difference between normal and automatic triggering.*

4. *You can also see the difference between the two triggering modes by using channel 2, even with that channel coupled to GND for ground. Change both the vertical display mode and the INT (2215A: A&B INT) switches to CH 2. With NORM triggering, there's no signal; with P-P AUTO, you'll see the baseline. Try it.*

External Triggering Of Scope (1)

Trigger Sources

Trigger sources are grouped into two categories that depend on whether the trigger signal is provided internally or externally. The source makes no difference in how the trigger circuit operates, but internal triggering usually means your scope is triggering on the same signal that it is displaying. That has the obvious advantage of letting you see where you're triggering.

Triggering on one of the channels works just like it sounds: you've set the scope to trigger on some part of the waveform present on that channel.

External Triggering Of Scope (2)

But triggering on the displayed signal isn't always what you need, so external triggering is also available. It often gives you more control over the display. To use an external trigger, you set the SOURCE switch to its EXT position and connect the triggering signal to the BNC connector marked EXT INPUT

	Switch Positions	
Trigger Source	SOURCE	INT
channel 1 only	INT	CH 1
channel 2 only	INT	CH 2
external	EXT	disabled
line	LINE	disabled

on the front panel. Occasions when external triggering is useful often occur in digital design and repair; there you might want to look at a long train of very similar pulses while triggering with an external clock or with a signal from another part of the circuit.

The LINE position on the SOURCE switch gives you another triggering possibility: the power line. Line triggering is useful anytime you're looking at circuits that are dependent on the power line frequency. Examples include devices like light dimmers and power supplies.

Scope Triggering Primer

Oscilloscope Trigger / Triggering Tutorial:

http://www.radio-electronics.com/info/t_and_m/oscilloscope/oscilloscope-trigger.php

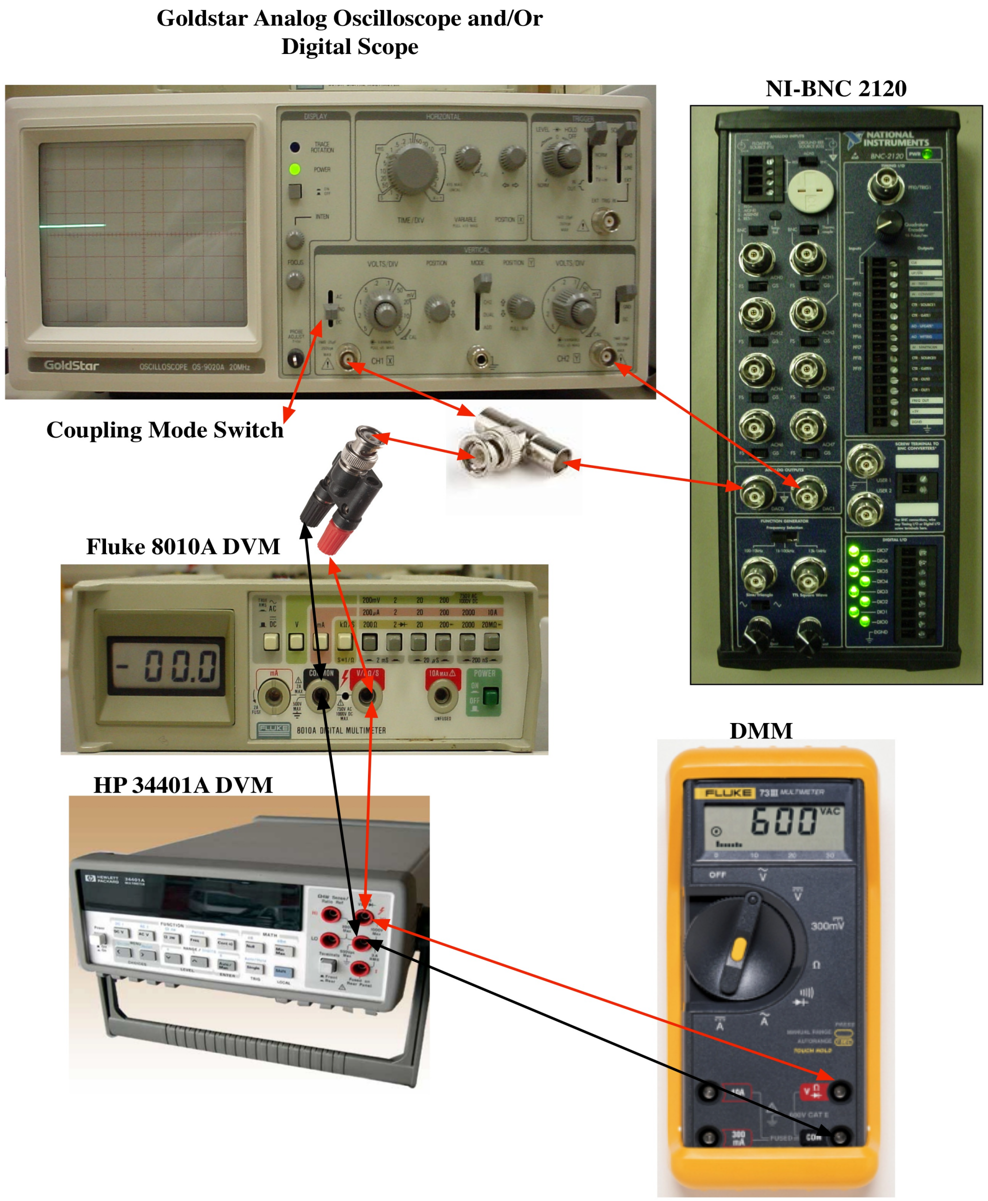
Digital Oscilloscope

Digital Oscilloscope

Same function as analog scope but No CRT screen … LCD Instead

Digital Scope Menu/Items

Lab Setup Part 1

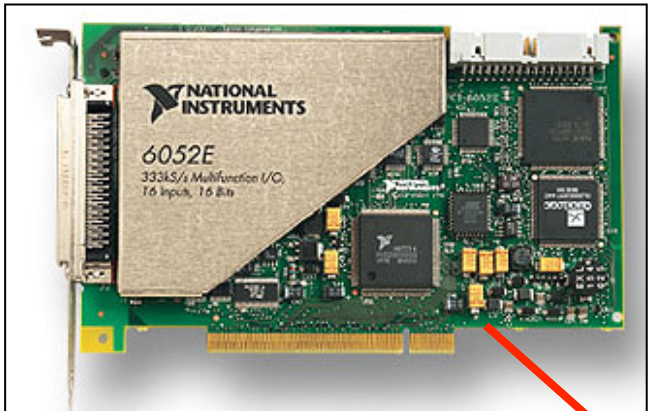


Connect DAC0 on the National Instruments **NI-BNC 2120** Connector Block the oscilloscope input channel 1, and DAC1 to scope's channel 2.

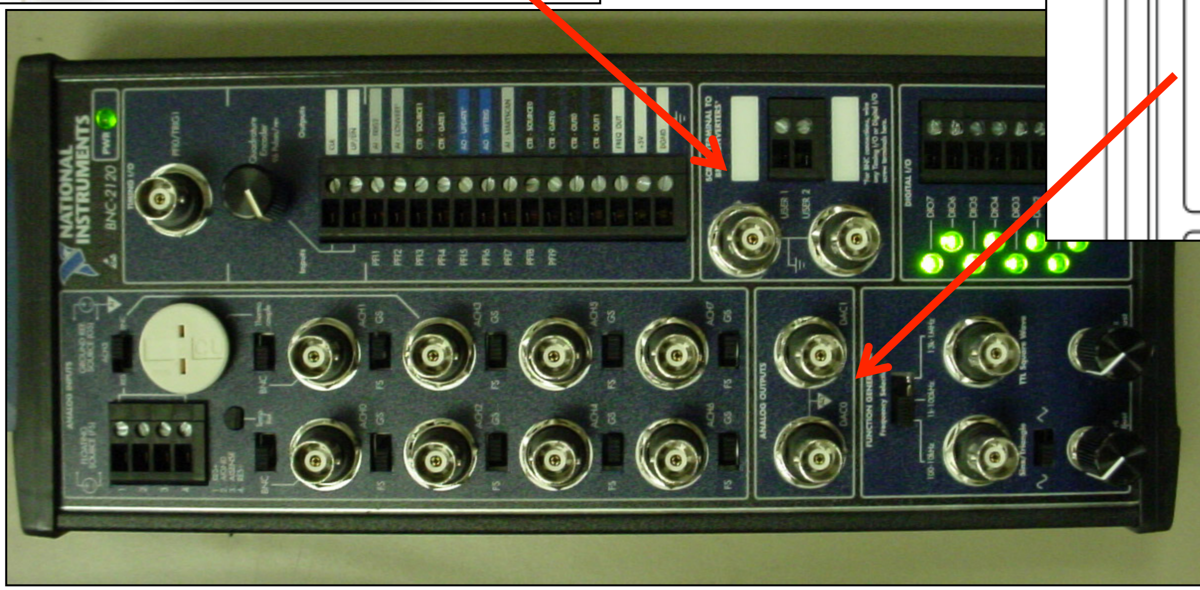
Also connect to the Fluke 8010a bench meter, HP 34401A meter, and handheld-DMM input terminals.

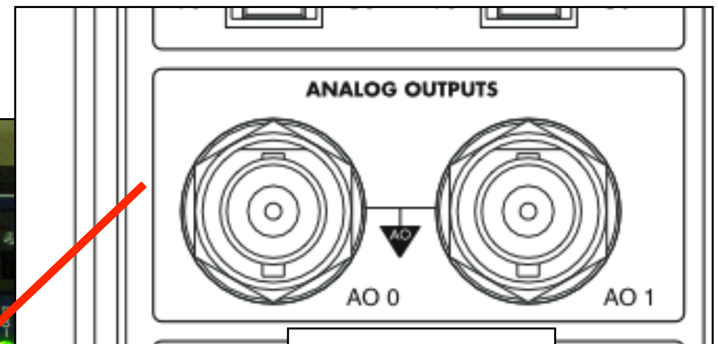
Set coupling mode switch to "AC"

•NI Multifunction I/O Card and Connector NI-BNC 2120 Block



• Will be used to generate waveforms for this Laboratory

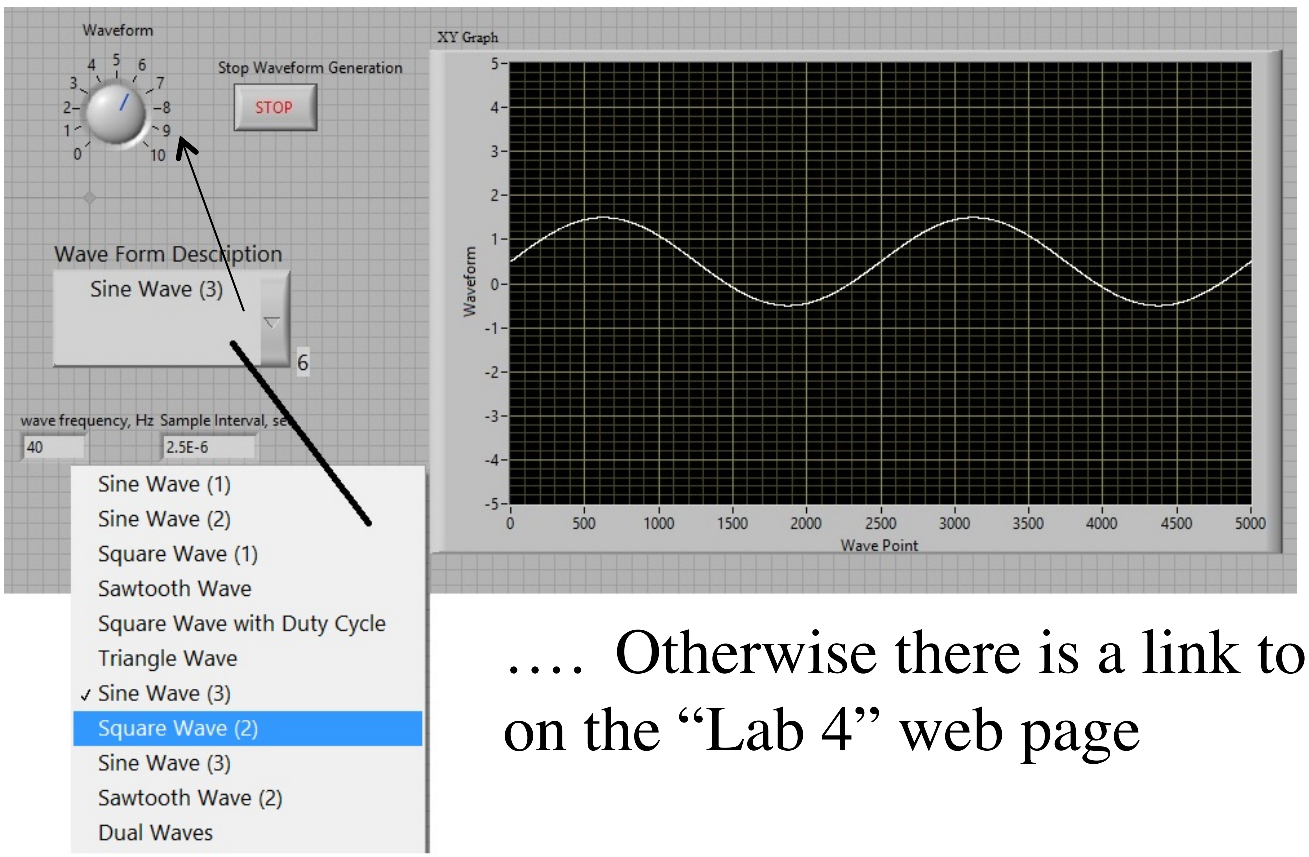




• Analog Outputs

Labview Waveform Generator for Laboratory

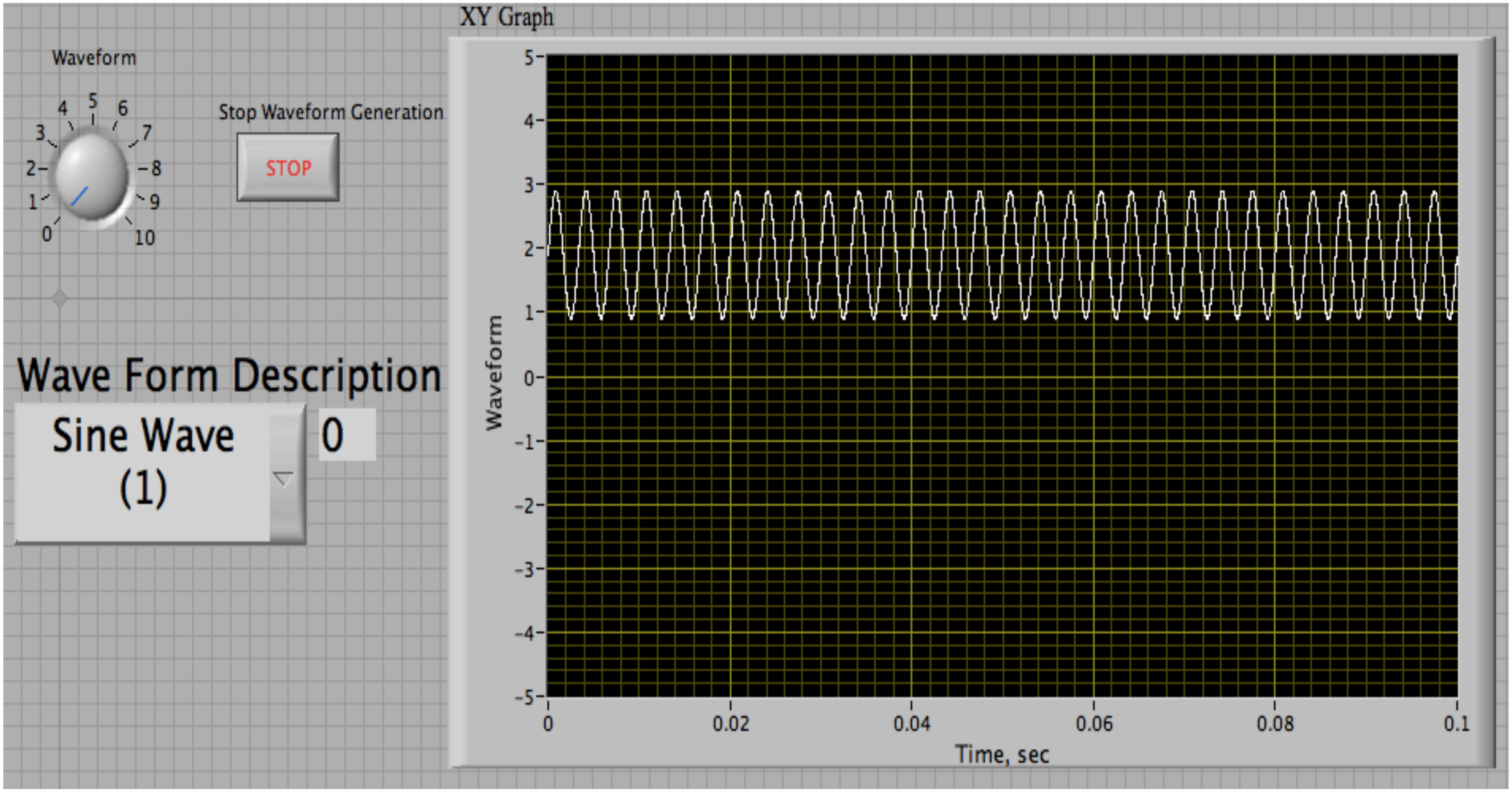
- *Signallab.vi* … should be a shortcut link on your desktop



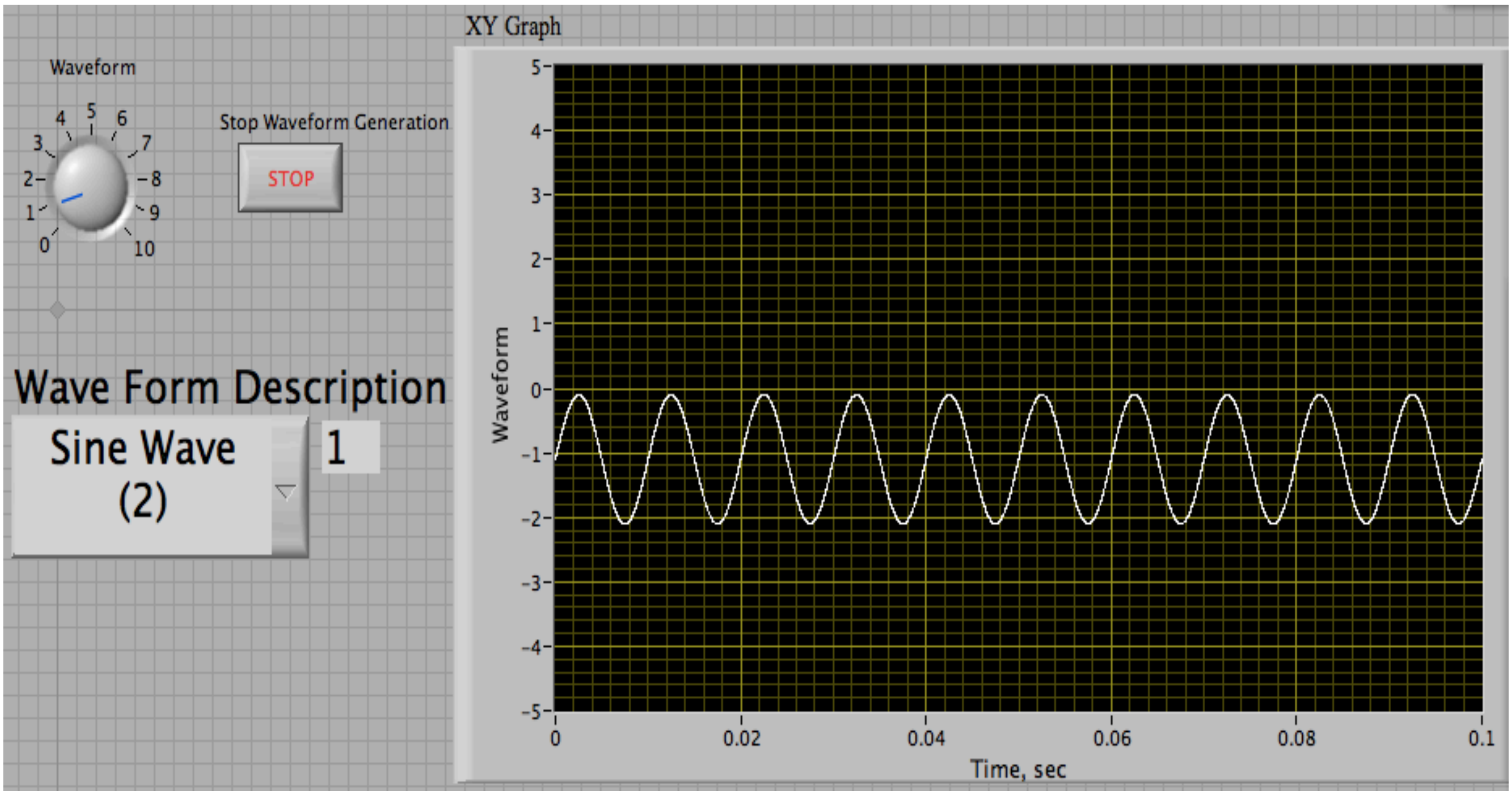
Outputs various selectable waveforms to DAC0 or DAC1 on BNC 2120

…. Otherwise there is a link to the file on the "Lab 4" web page

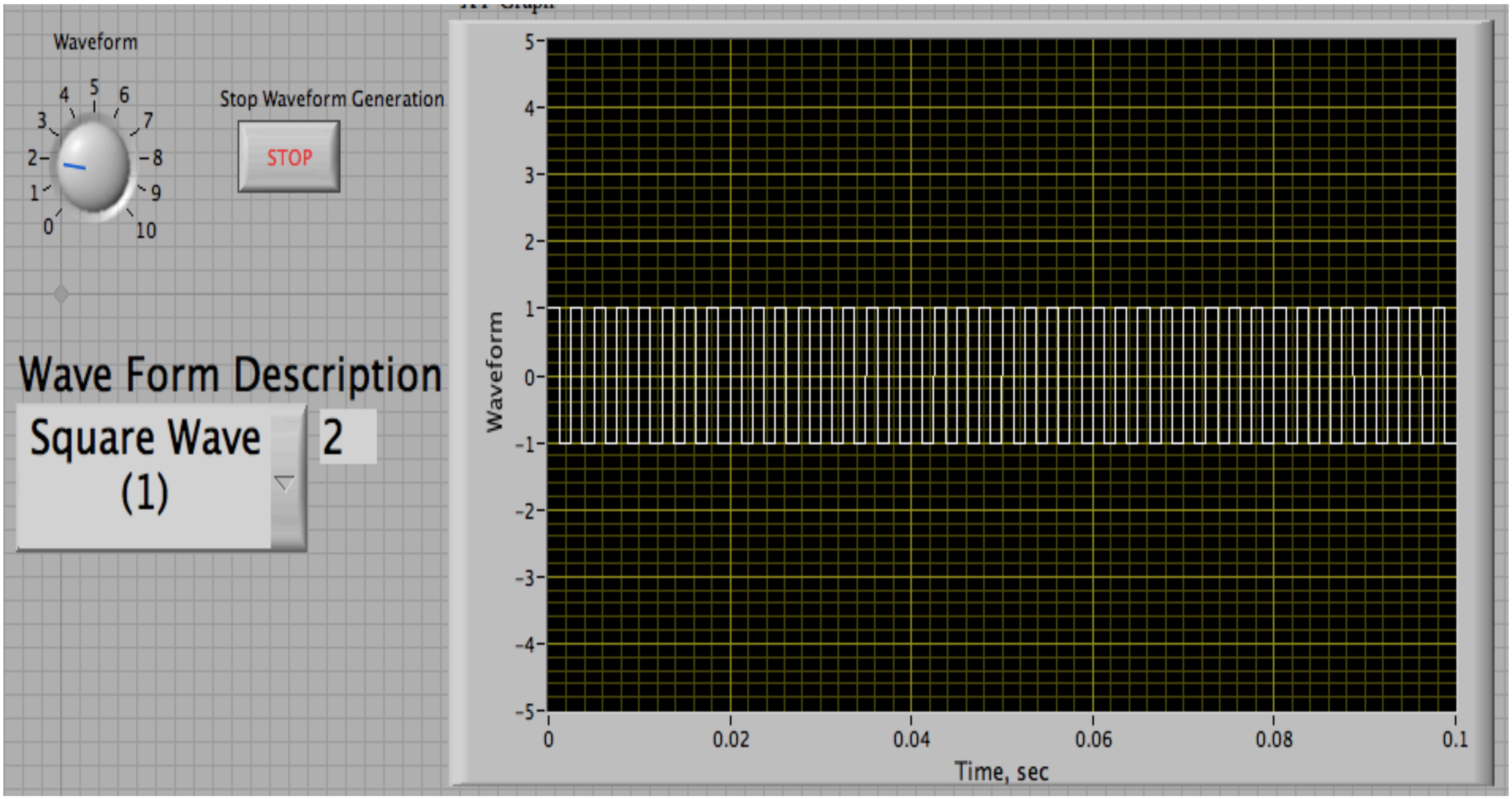
Wave Forms for Laboratory, Part 1 (1)



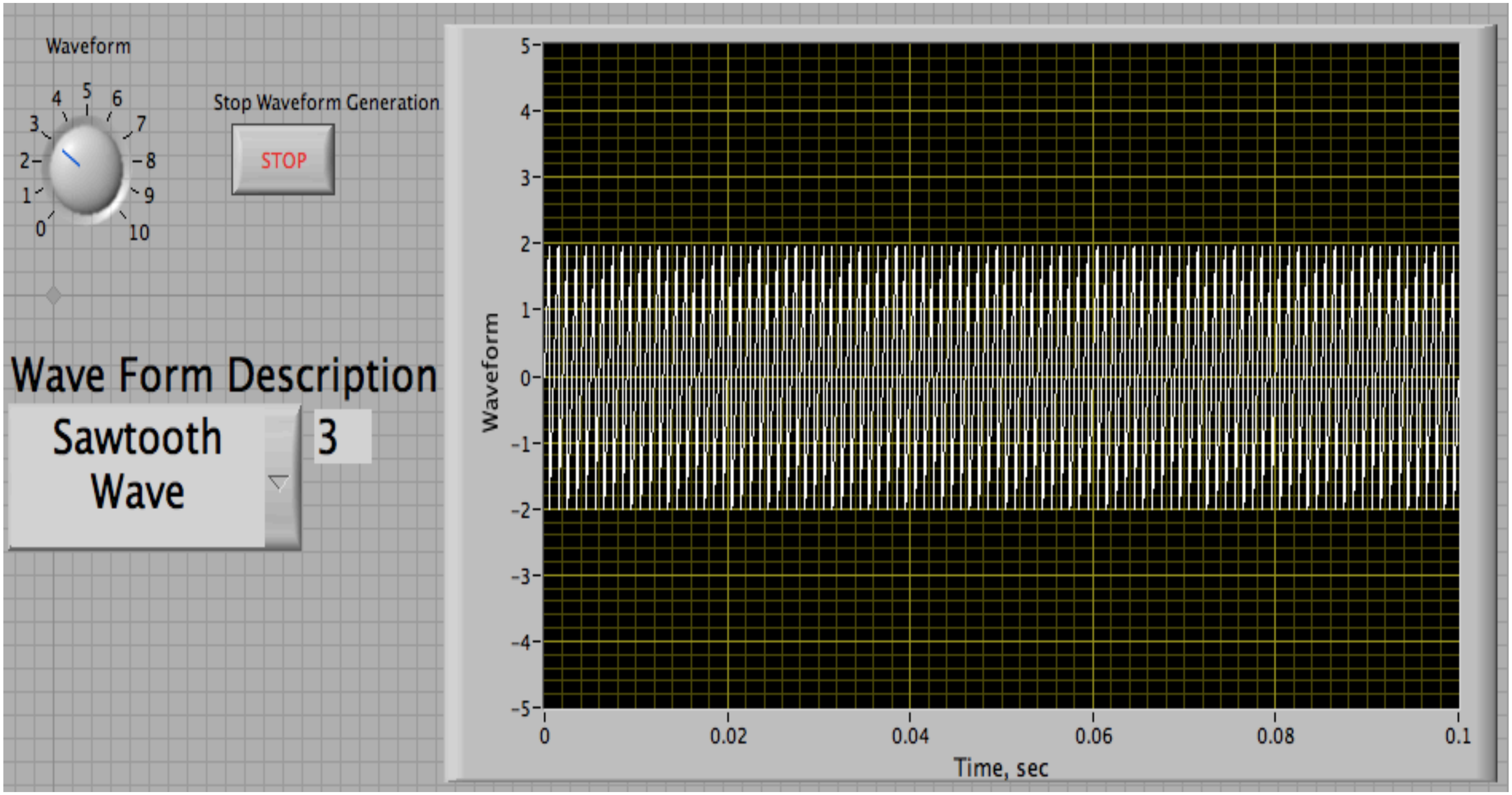
Wave Forms for Laboratory, Part 1 (2)



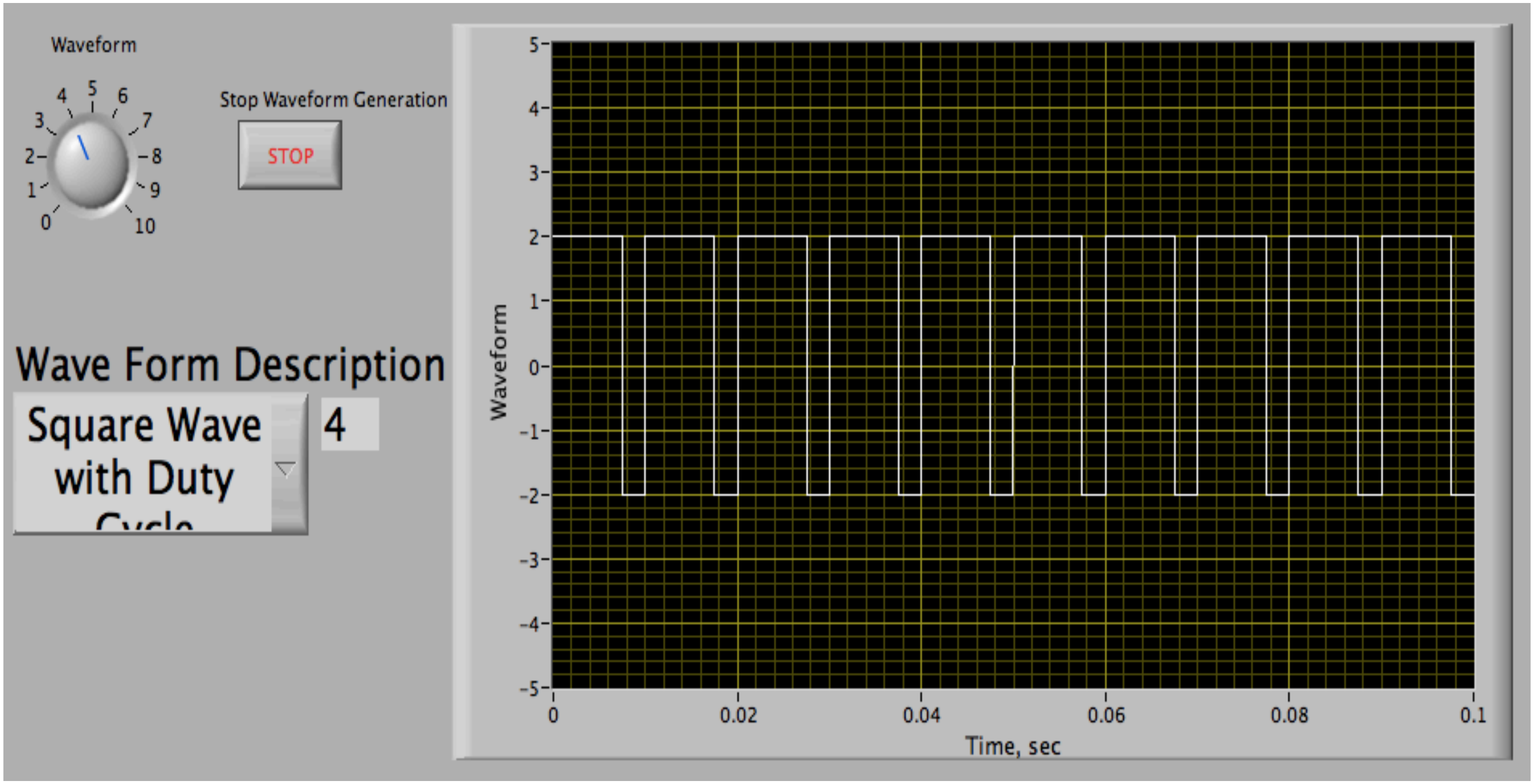
Wave Forms for Laboratory, Part 1 (3)



Wave Forms for Laboratory, Part 1 (4)

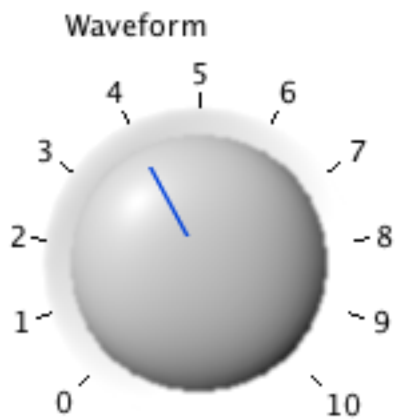


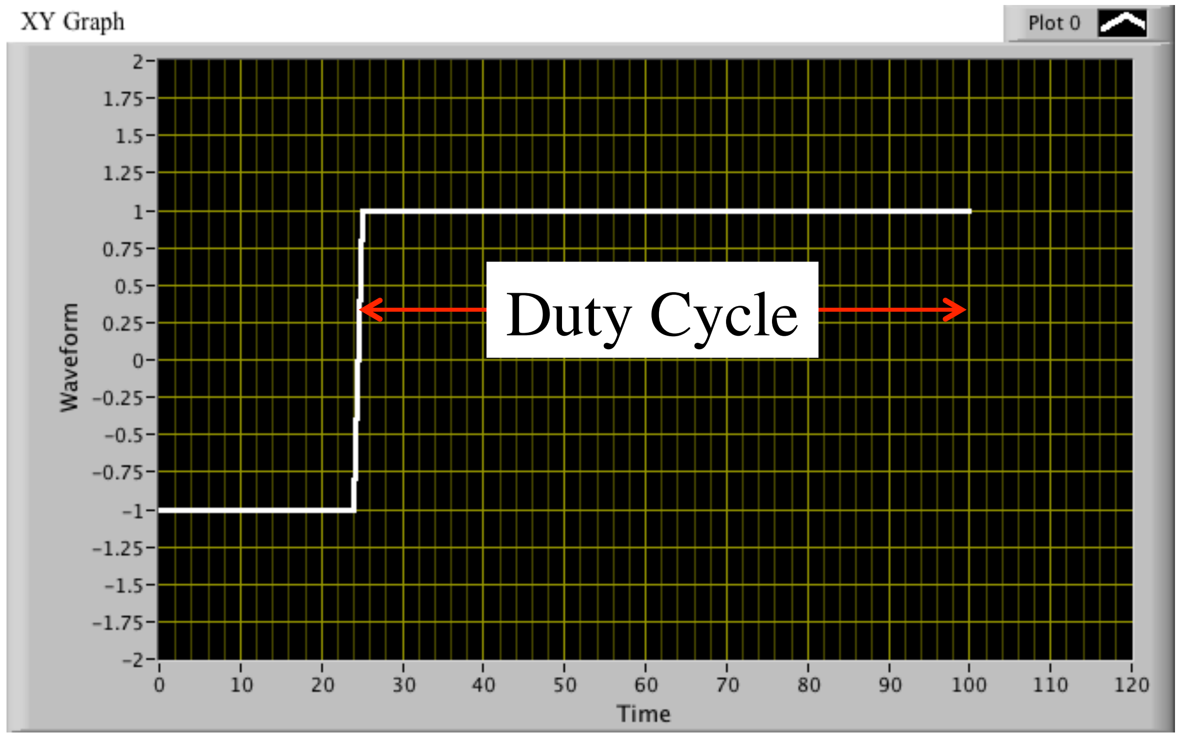
Wave Forms for Laboratory, Part 1 (5)



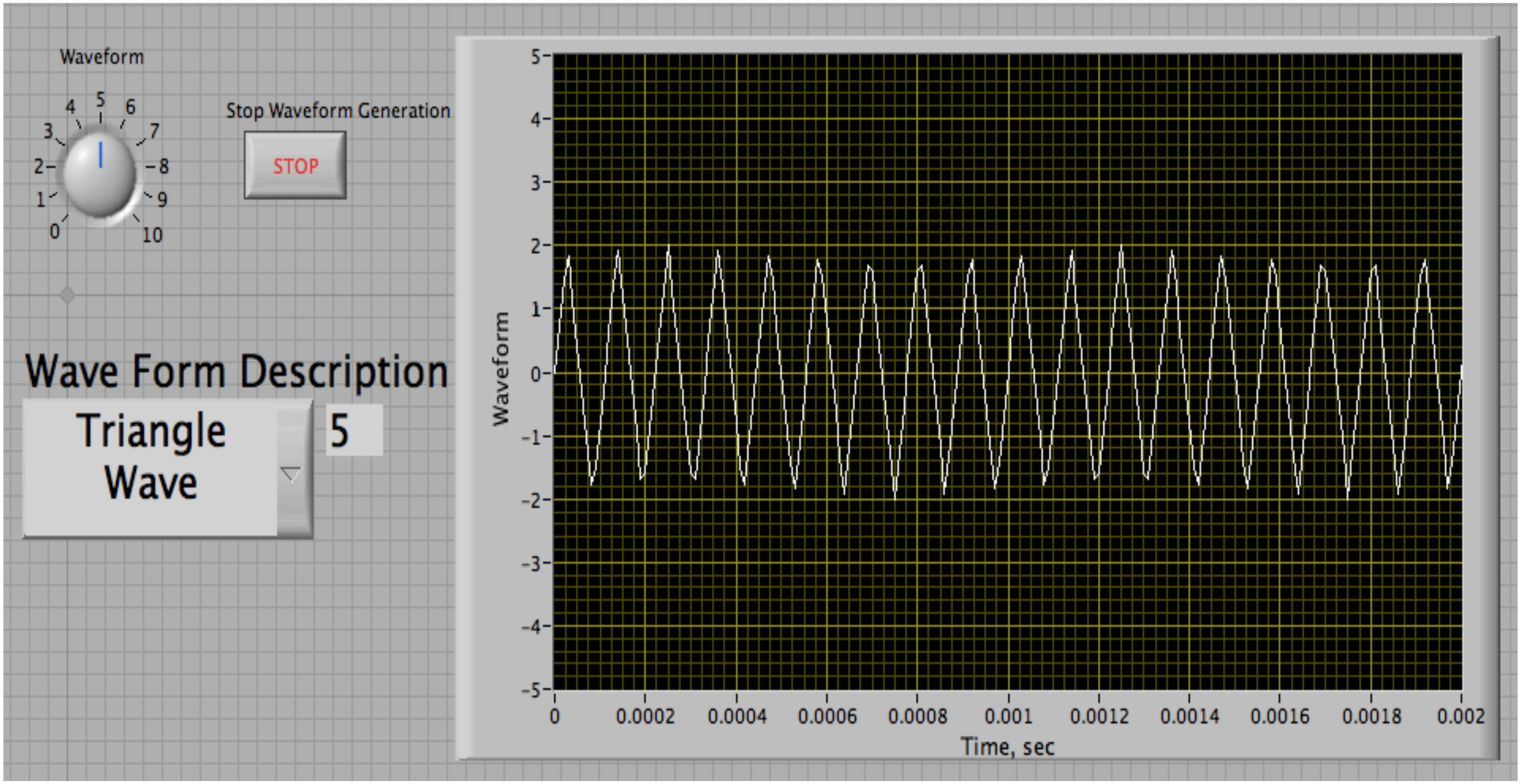
Wave Forms for Laboratory, Part 1 (6)

Square Wave with Duty Cycle Definition

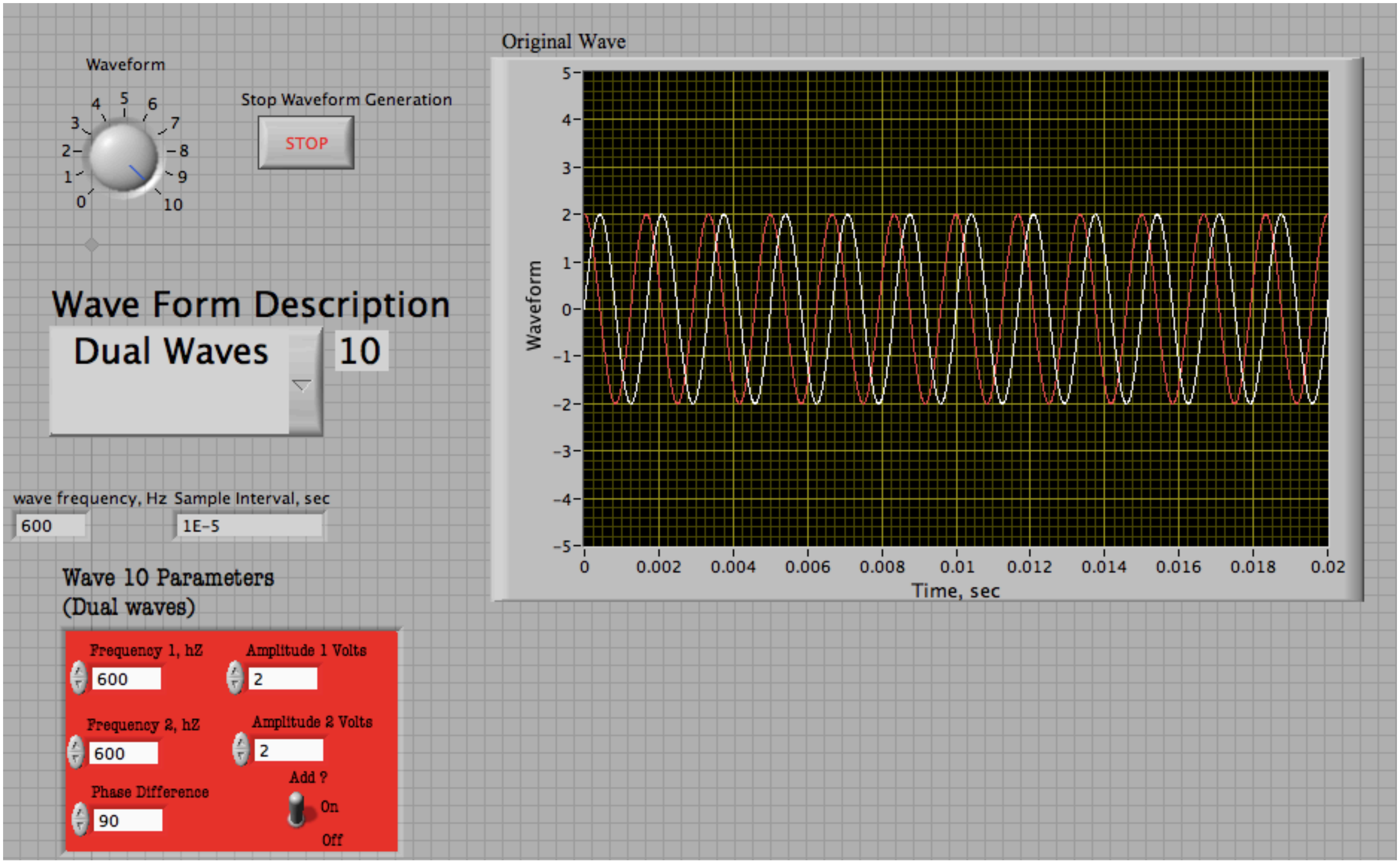




Wave Forms for Laboratory, Part 1 (7)



Wave Forms for Laboratory, Part 1 (8)



What Happens when we hit the "Add" Switch on the scope *(case 1)*

$$Trig\ Identity: \sin(x)+\sin(y)=2\cdot\sin\left(\frac{x+y}{2}\right)\cdot\cos\left(\frac{x-y}{2}\right)$$

$$y(t)=A_0\cdot\sin(\omega_0\cdot t)+A_0\cdot\sin(\omega_1\cdot t+\phi)=2\cdot A_0\cdot\sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t+\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t-\phi}{2}\right)=$$

$$\rightarrow 2\cdot A_0\cdot\left[\sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+\cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\right]\times\left[\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{-\phi}{2}\right)-\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{-\phi}{2}\right)\right]=$$

$$\left[\begin{array}{l}\sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+\\ \cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+\\ \sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)\cdot\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)+\\ \cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\cdot\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\end{array}\right]=2\cdot A_0\cdot\left[\begin{array}{l}\sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+\\ \cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+\\ \sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)\cdot\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)+\\ \cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\cdot\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\end{array}\right]$$

What Happens when we hit the "Add" Switch on the scope (2)

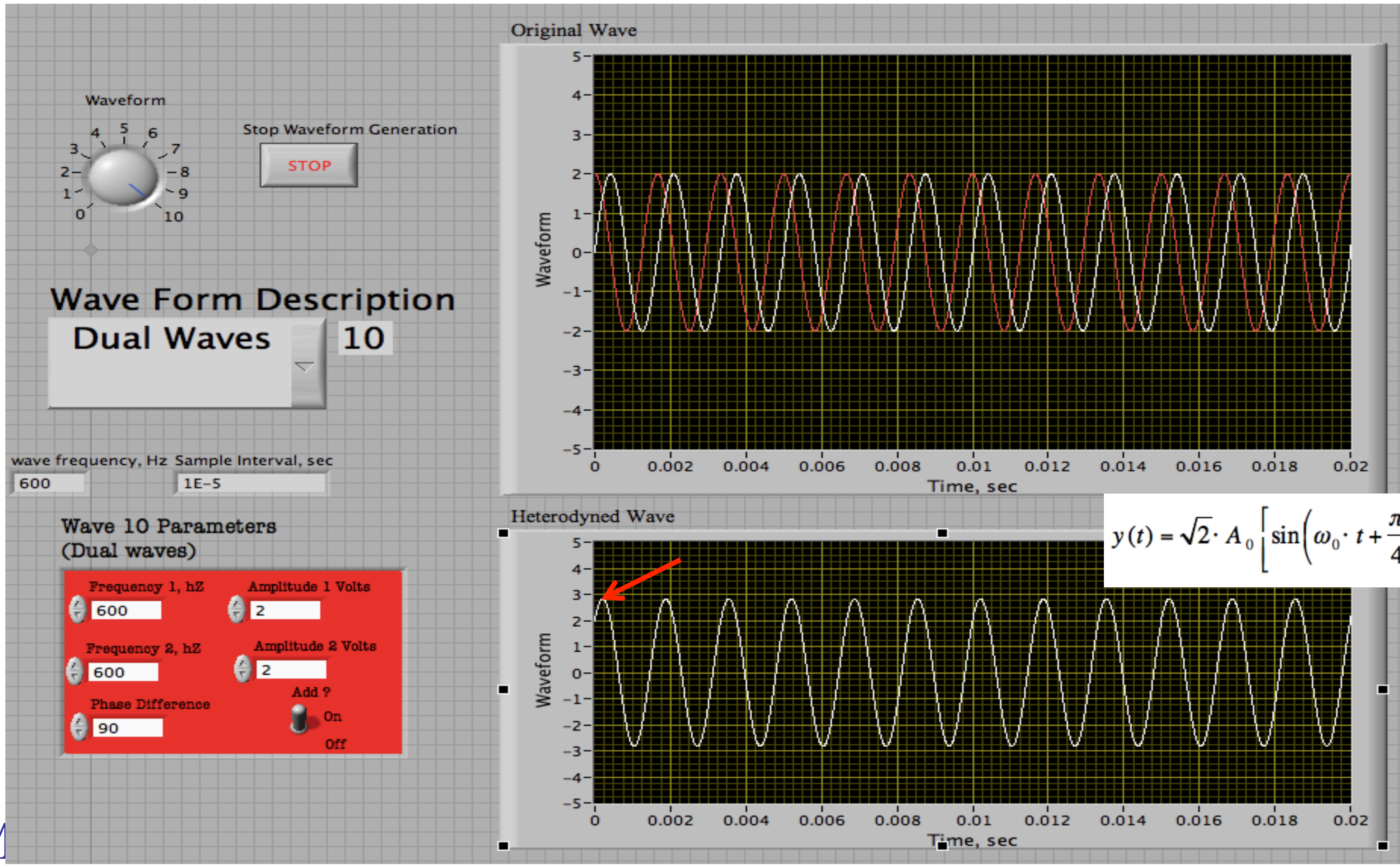
$$\rightarrow y(t) = 2\cdot A_0 \cdot \left[\begin{array}{l} \sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+ \\ \cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\cdot\cos\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)+ \\ \sin\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\cos\left(\frac{\phi}{2}\right)\cdot\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)+ \\ \cos\left(\frac{\omega_0\cdot t+\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right)\cdot\sin\left(\frac{\omega_0\cdot t-\omega_1\cdot t}{2}\right)\cdot\sin\left(\frac{\phi}{2}\right) \end{array}\right]$$

Case 1:

$$\phi = 90^0 = \frac{\pi}{2}_{\ radians} \rightarrow \begin{array}{l} \cos\left(\frac{\phi}{2}\right)=\cos\left(\frac{\pi}{4}\right)=\frac{\sqrt{2}}{2} \\ \sin\left(\frac{\phi}{2}\right)=\sin\left(\frac{\pi}{4}\right)=\frac{\sqrt{2}}{2} \\ \omega_0=\omega_1 \end{array}$$

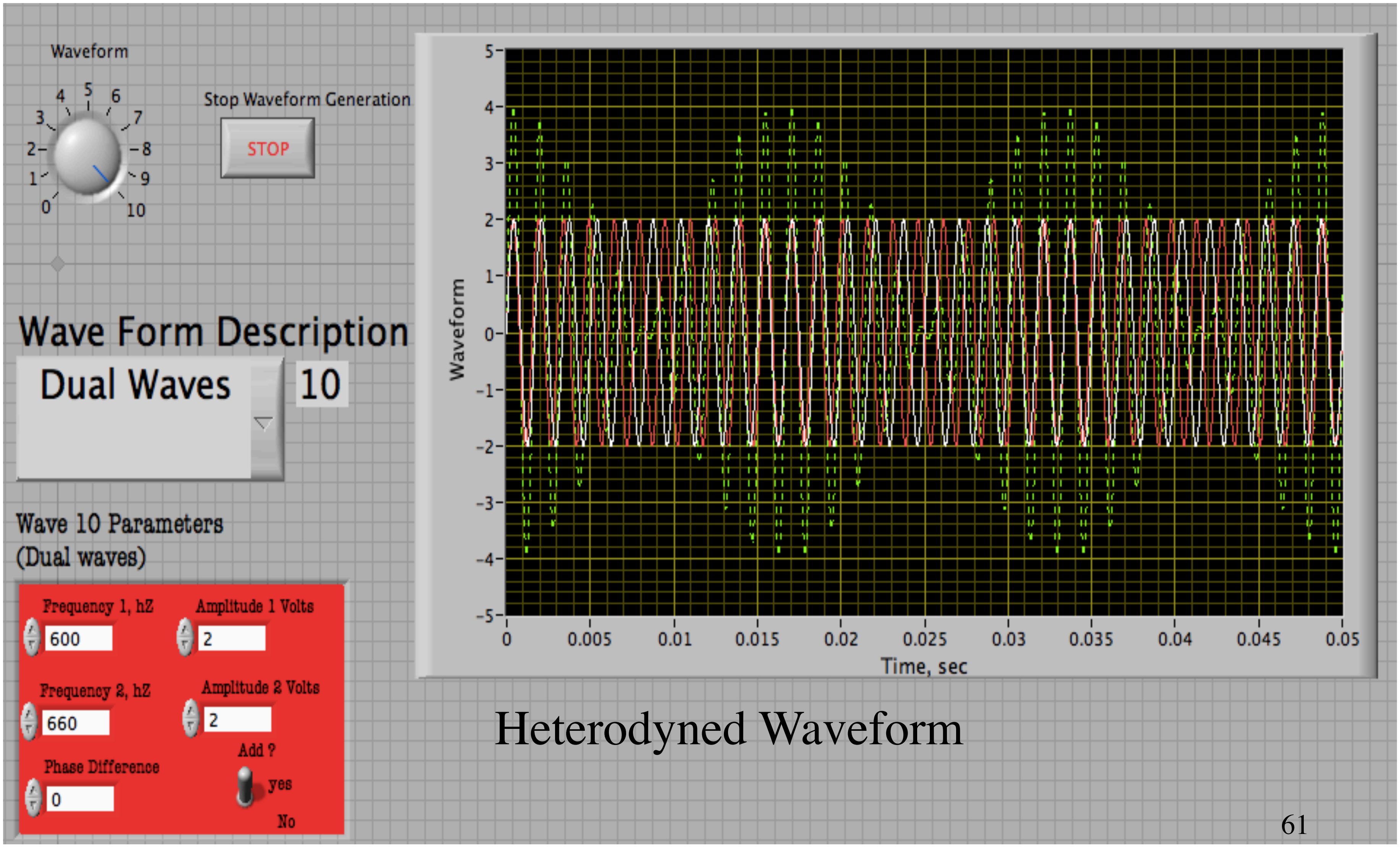
$$\rightarrow y(t) = \begin{array}{l} 2\cdot A_0\cdot\left[\left(\frac{\sqrt{2}}{2}\right)^2\sin(\omega_0\cdot t)+\left(\frac{\sqrt{2}}{2}\right)^2\cos(\omega_0\cdot t)\right]= \\ A_0\cdot\left[\sin(\omega_0\cdot t)+\cos(\omega_0\cdot t)\right]= \\ A_0\cdot\frac{2}{\sqrt{2}}\left[\sin(\omega_0\cdot t)\cdot\frac{\sqrt{2}}{2}+\cos(\omega_0\cdot t)\cdot\frac{\sqrt{2}}{2}\right]= \\ \sqrt{2}\cdot A_0\left[\sin\left(\omega_0\cdot t+\frac{\pi}{4}\right)\right]...QED! \end{array}$$

What Happens when we hit the "Add" Switch on the scope (3)



$$y(t) = \sqrt{2} \cdot A_0 \left[\sin\left(\omega_0 \cdot t + \frac{\pi}{4} \right) \right]$$

Wave Forms for Laboratory, Part 1 (9)



Heterodyned Waveform

What Happens when we hit the “Add” Switch on the scope *(case 2)*

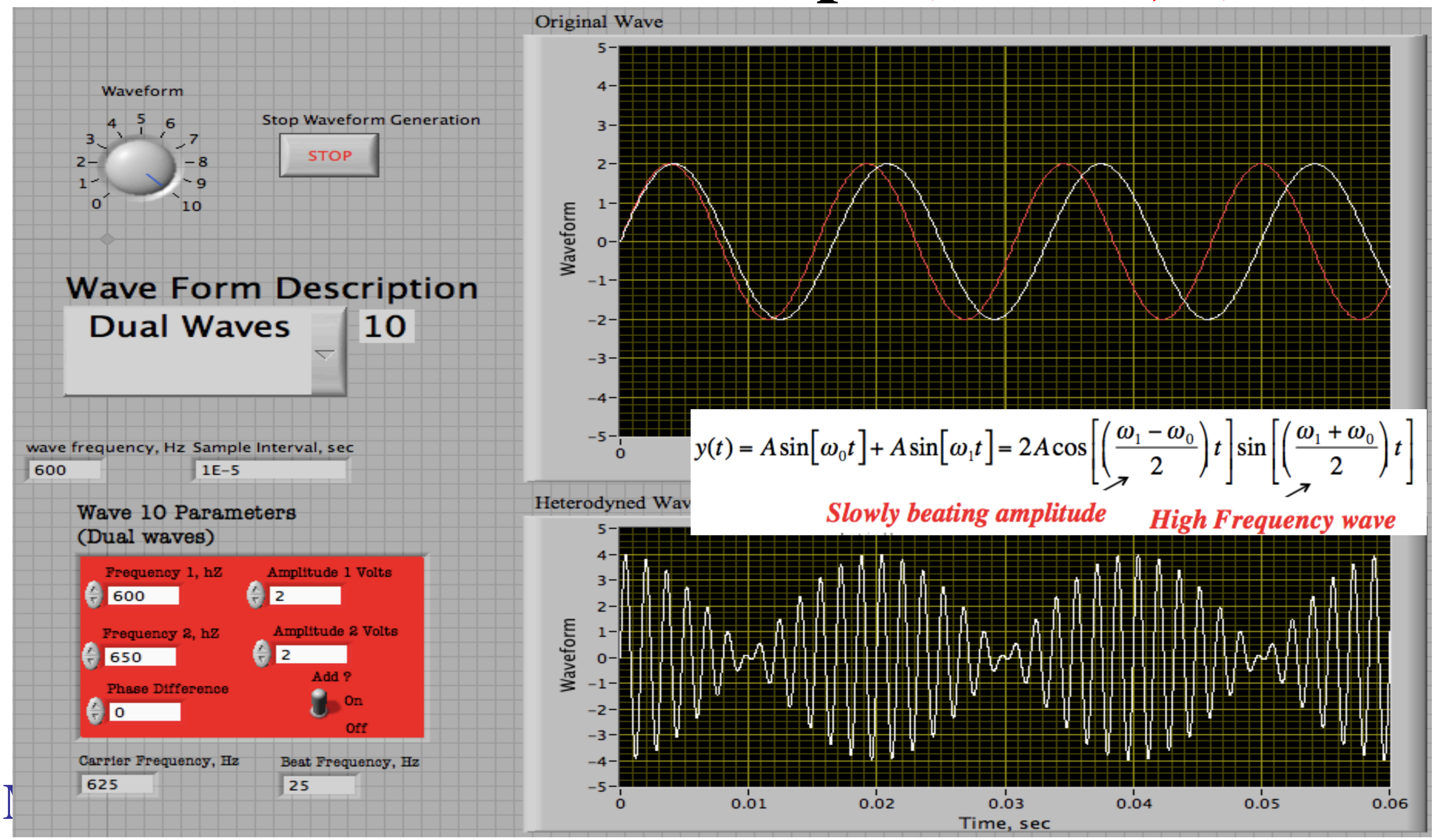
$$y(t) = A_0 \cdot \sin(\omega_0 \cdot t) + A_0 \cdot \sin(\omega_1 \cdot t + \phi) =$$

$$\left.\begin{array}{l} \phi = 0^0 \\ \omega_0 \neq \omega_1 \end{array}\right| \rightarrow \quad 2 \cdot A_0 \cdot \left[\begin{array}{l} \sin\left(\dfrac{\omega_0 \cdot t + \omega_1 \cdot t}{2}\right) \cdot \underset{1}{\cos\left(\dfrac{\phi}{2}\right)} \cdot \cos\left(\dfrac{\omega_0 \cdot t - \omega_1 \cdot t}{2}\right) \cdot \overset{1}{\cos\left(\dfrac{\phi}{2}\right)} + \\ \cos\left(\dfrac{\omega_0 \cdot t + \omega_1 \cdot t}{2}\right) \cdot \cancel{\sin\left(\dfrac{\phi}{2}\right)} \cdot \cos\left(\dfrac{\omega_0 \cdot t - \omega_1 \cdot t}{2}\right) \cdot \cos\left(\dfrac{\phi}{2}\right) + \\ \sin\left(\dfrac{\omega_0 \cdot t + \omega_1 \cdot t}{2}\right) \cdot \cos\left(\dfrac{\phi}{2}\right) \cdot \cancel{\sin\left(\dfrac{\omega_0 \cdot t - \omega_1 \cdot t}{2}\right)} \cdot \cancel{\sin\left(\dfrac{\phi}{2}\right)} + \\ \cos\left(\dfrac{\omega_0 \cdot t + \omega_1 \cdot t}{2}\right) \cdot \cancel{\sin\left(\dfrac{\phi}{2}\right)} \cdot \sin\left(\dfrac{\omega_0 \cdot t - \omega_1 \cdot t}{2}\right) \cdot \cancel{\sin\left(\dfrac{\phi}{2}\right)} \end{array} \right] =$$

Carrier Frequency *Beat Frequency*

$$2 \cdot A_0 \cdot \left[\sin\left(\frac{\omega_0 \cdot t + \omega_1 \cdot t}{2}\right) \cdot \cos\left(\frac{\omega_0 \cdot t - \omega_1 \cdot t}{2}\right) \right]$$

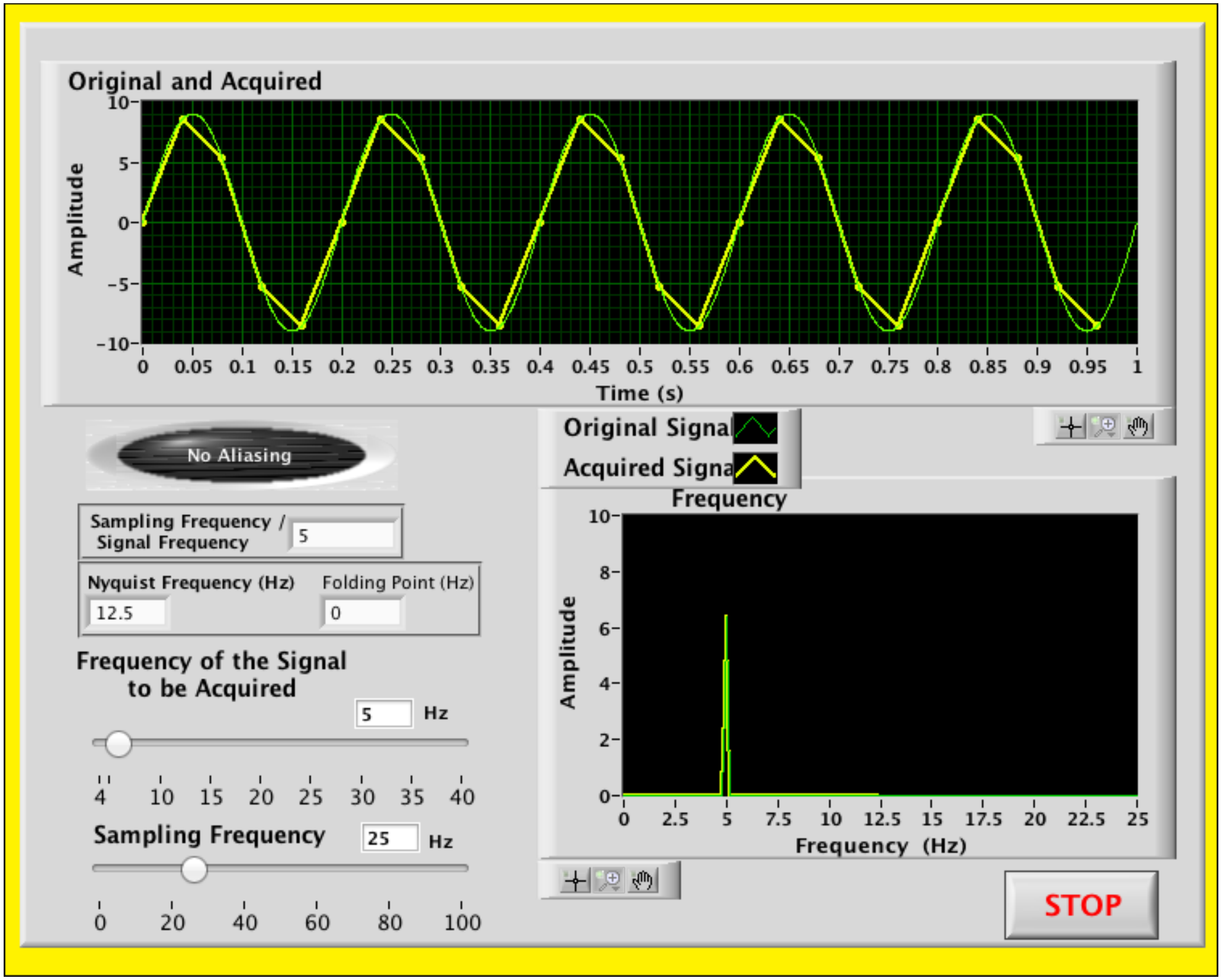
What Happens when we hit the “Add” Switch on the scope (Case 2, 2)



$$y(t) = A\sin\left[\omega_0 t\right] + A\sin\left[\omega_1 t\right] = 2A\cos\left[\left(\frac{\omega_1-\omega_0}{2}\right)t\right]\sin\left[\left(\frac{\omega_1+\omega_0}{2}\right)t\right]$$

Slowly beating amplitude *High Frequency wave*

Lab 4 Part 2, Effects of Signal Aliasing



UtahState UNIVERSITY

Mechanical & Aerospace Engineering

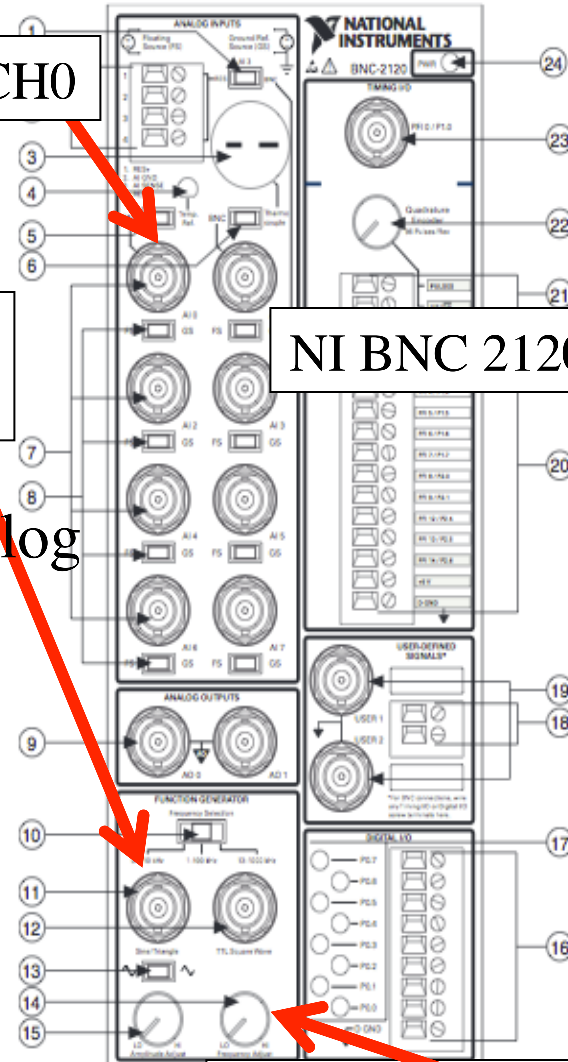
Lab Setup: Part 2

NI BNC 2120

Connect BNC 2120 Signal Generator Output to 'Scope Chan 1 and BNC 2120 ACH0 *(Analog Input)*

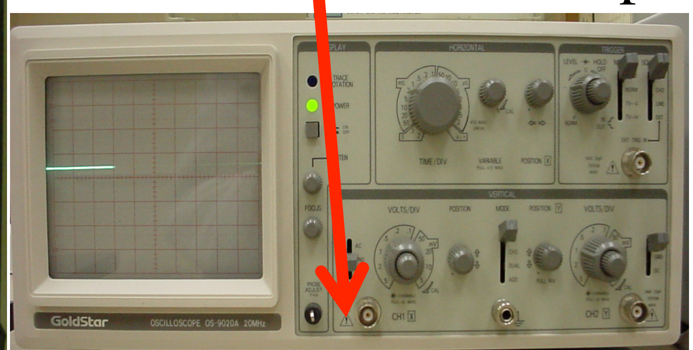
Signal Generator

ACH0



NI BNC 2120

Connect to Analog and Digital Oscilloscope

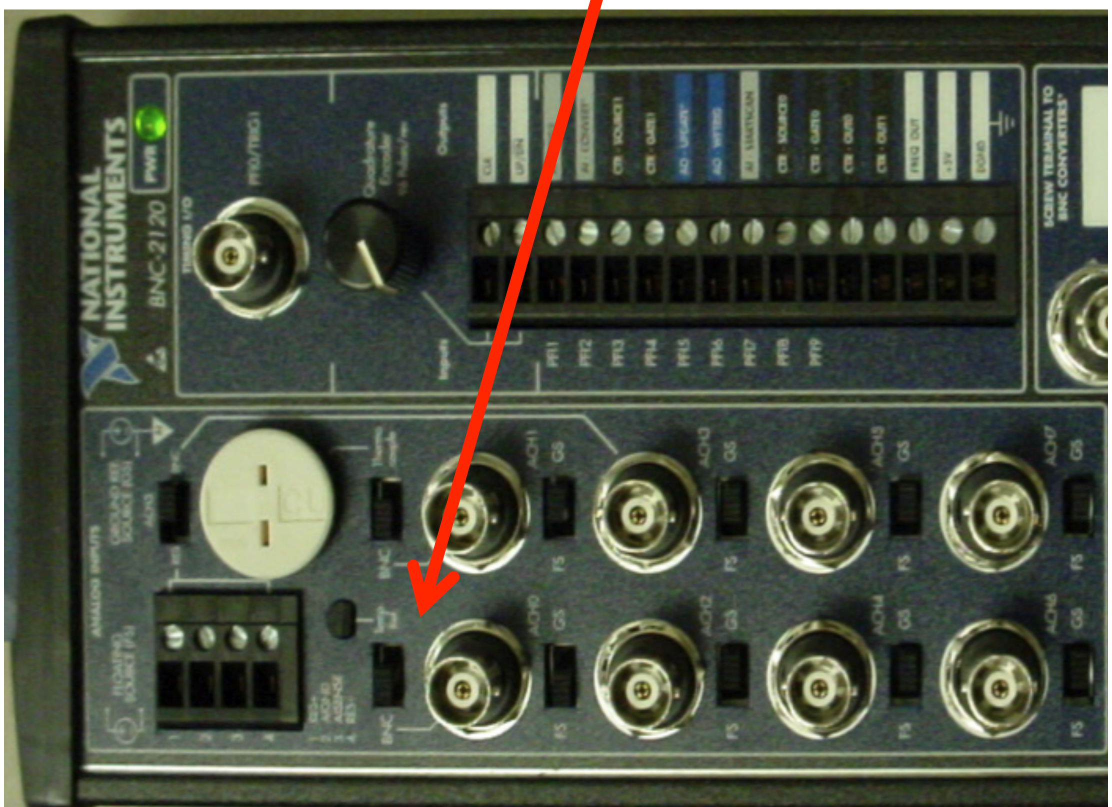


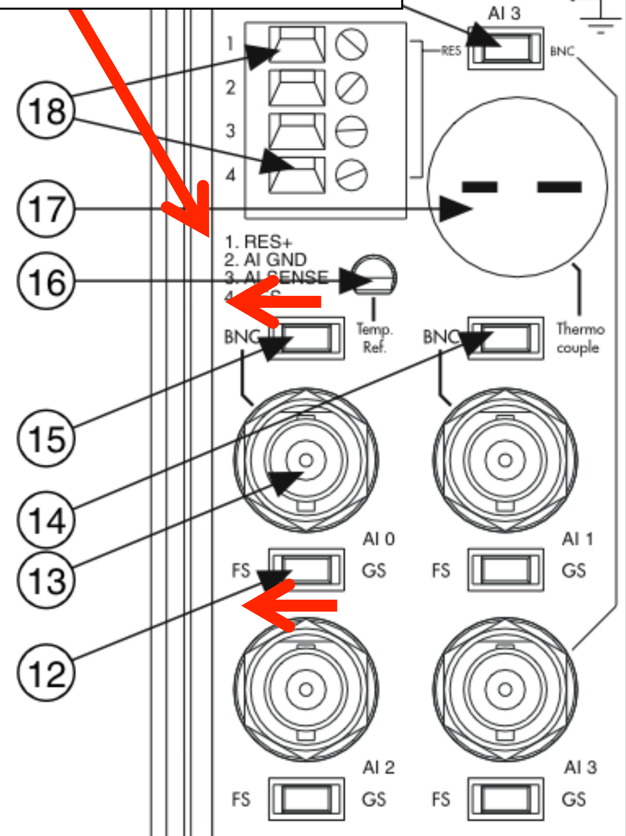
- Frequency and Amplitude Settings

NI BNC 2120 Connector Block Analog Input Channels

- Analog Input Channels

Make sure switches are set to “BNC” and “FS”





You are Going to Populate this Table for Both Sine and Triangle Waves

Table 3: Part 2 Lab Test Results.

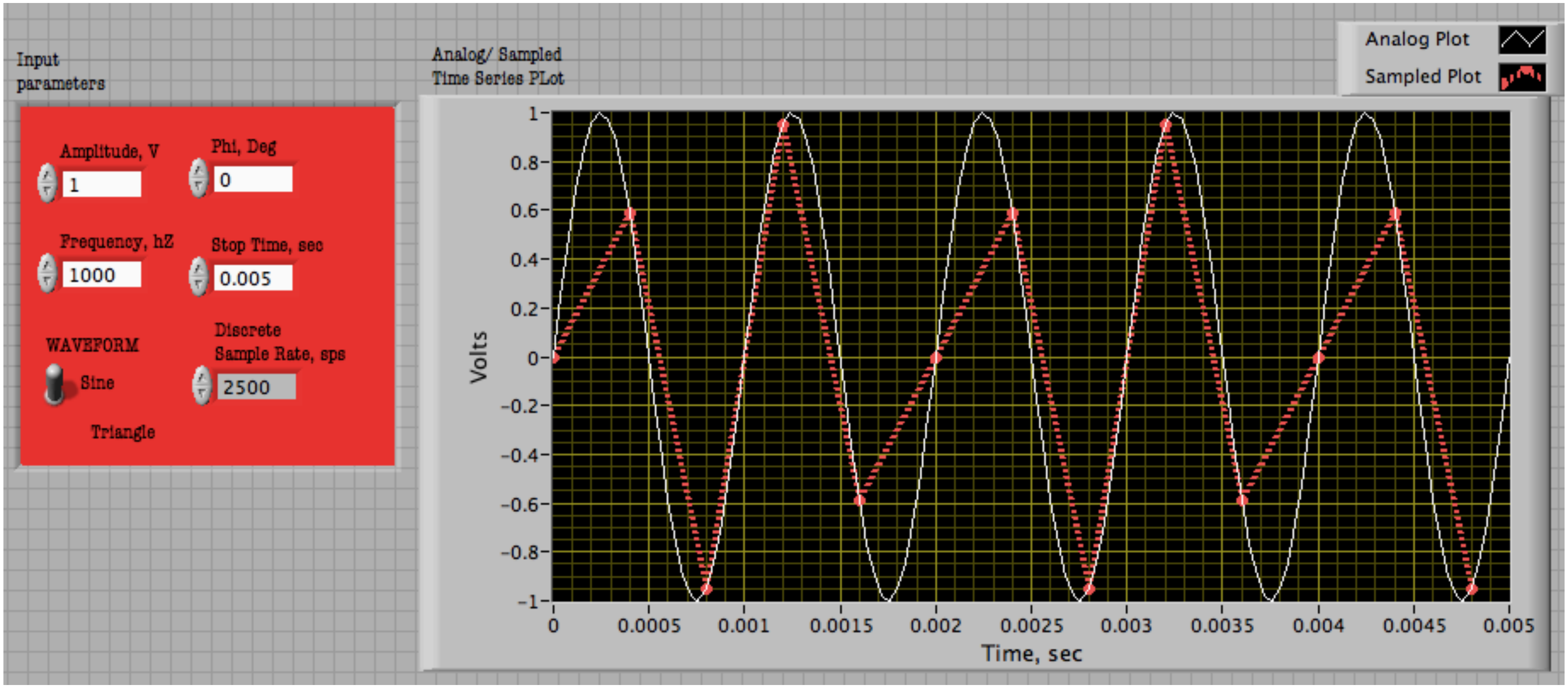
Wave	Set P-P Voltage	Set Frequency	Sample rate	Observed P-P Voltage from *DAQlab.vi*	Observed frequency from *DAQlab.vi*
Sine					
1	2 V	1000 Hz	15,000 sps		
2	2 V	1000 Hz	2500 sps		
3	2 V	1000 Hz	2000 sps		
4	2 V	1000 Hz	750 sos		
5	2 V	1000 Hz	500 sps		
6	2 V	1000 Hz	250 sps		
7	2 V	1000 Hz	100 sps		
*	*	*	*	*	*

You are Going to Populate this Table for Both Sine and Triangle Waves

Sine					
8	2 V	250 Hz	15,000 sps		
9	2 V	250 Hz	2500 sps		
10	2 V	250 Hz	2000 sps		
11	2 V	250 Hz	750 sps		
12	2 V	250 Hz	500 sps		
13	2 V	250 Hz	250 sps		
14	2 V	250 Hz	100 sps		
*	*	*	*	*	*

Use Oscilloscope to set the amplitude and frequency of BNC 2120 Waveform Generator(s)

Part 2 Example Waveforms



Part 2 Example Waveforms (2)